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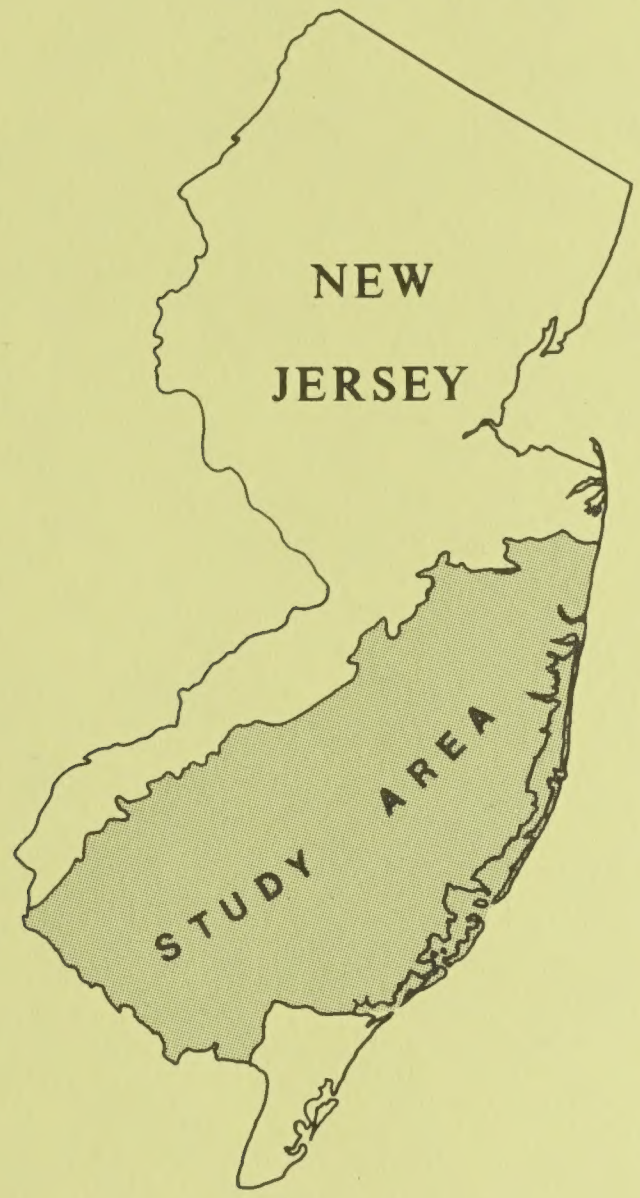
# CORROSIVENESS OF GROUND WATER IN THE KIRKWOOD-COHANSEY AQUIFER SYSTEM OF THE NEW JERSEY COASTAL PLAIN

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 90-4180

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# CORROSIVENESS OF GROUND WATER IN THE KIRKWOOD-COHANSEY AQUIFER SYSTEM OF THE NEW JERSEY COASTAL PLAIN

By Julia L. Barringer, George R. Kish, and Anthony J. Velnich

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NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ENERGY

West Trenton, New Jersey
1993

U.S. DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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## CONVERSION FACTORS AND VERTICAL DATUM

| Multiply | By | To Obtain |
|---|---|---|
| | **Length** | |
| inch (in.) | 2.54 | centimeter |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| | **Area** | |
| square mile ($mi^2$) | 2.590 | square kilometer |
| | **Weight** | |
| microgram ($\mu g$) | $3.527 \times 10^{-8}$ | ounces, avoirdupois |
| milligram (mg) | 0.00003527 | ounces, avoirdupois |
| gram (g) | 0.03527 | ounces, avoirdupois |
| kilogram (kg) | 2.205 | pounds, avoirdupois |
| | **Volume** | |
| liter (L) | 33.81 | ounces, fluid |

Temperature-conversion formula

| | | |
|---|---|---|
| degree Celsius (°C) | 1.8 x °C + 32 = °F | degree Fahrenheit (°F) |

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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## ABSTRACT

Ground water from the unconfined part of the Kirkwood-Cohansey aquifer system in the New Jersey Coastal Plain typically is corrosive--that is, it is acidic, soft, and has low concentrations of alkalinity. Corrosive ground water has the potential to leach trace elements and asbestos fibers from plumbing materials used in potable-water systems, thereby causing potentially harmful concentrations of these substances in drinking water.

Corrosion indices were calculated from water-quality data for 370 wells in the unconfined Kirkwood-Cohansey aquifer system. The indices indicate that most of the water from the unconfined part of the Kirkwood-Cohansey aquifer system is highly corrosive. Values of the Langelier Saturation Index are predominantly negative, indicating that the water is undersaturated with respect to calcium carbonate and, therefore, is potentially corrosive. Values of the Aggressive Index, a similar estimator of the aggressiveness (or corrosiveness) of water, range from 3.9 (highly aggressive or corrosive) to 11.9 (moderately aggressive or corrosive). The median Aggressive Index value calculated for the 370 wells is 6.0, a value indicative of highly corrosive water. Moderately corrosive ground water is found in some coastal areas of Ocean County. Isolated instances of moderately corrosive water are found in northern Ocean County, and in Burlington, Camden, and Salem Counties. In the vicinity of Ocean County, corrosion-index values appear to change little with depth, but in Atlantic and Salem Counties, the corrosiveness of ground water appears to decrease with depth.

Analyses of standing tap water from newly constructed homes in the Coastal Plain show that concentrations of lead and other trace elements are significantly higher than those in ambient ground water. The elevated trace-element concentrations are attributed to the corrosion of plumbing materials by ground water. Results of the tap-water analyses substantiate the corrosiveness of Kirkwood-Cohansey ground water, as estimated by corrosion index values.

## INTRODUCTION

Elevated concentrations of lead in drinking water have been documented in the United Kingdom and in some areas of the United States (Beattie and others, 1972; Karalekas and others, 1976; O'Brien, 1976; Matthew, 1981; Lassovszky, 1984). In virtually all instances, the cause of the elevated lead levels has been shown to be the leaching action of corrosive water on pipes and pipe solder (Karalekas and others, 1976; Lovell and others, 1978; de Mora and Harrison, 1984; Murrell, 1985). Leaching generally is most severe in plumbing that is less than 5 years old; deposits that build up in older pipes tend to prevent the attack of corrosive water. Kish and others (1987) traced elevated lead concentrations in tap water from three New Jersey communities to the corrosive nature of ground water in the Kirkwood-Cohansey aquifer system. Corrosive waters also are responsible for the leaching of metals other than

lead (Maessen and others, 1985), and for the disintegration of asbestos-cement pipe (Stuart, M., U.S. Water News, 1986).

The deleterious effects of lead in drinking water on human health have been known for many years. In a number of recent studies, summarized by Patterson and O'Brien (1979), elevated concentrations of lead (in excess of 0.05 mg/L (milligrams per liter)) in drinking water have been implicated in hyperactivity in children, as well as in reduced levels of intelligence and mental retardation. Hypertension, cardiovascular disease, and renal insufficiency also are associated with excessive concentrations of lead.

Metals other than lead may be leached from water-distribution systems, and some may adversely affect human health. Cadmium, an impurity in zinc, has been found to cause renal injury in rats at levels in excess of 30 mg/L. Although copper and zinc are essential trace elements for animals and humans, both can be toxic to humans at levels of about 40 to 50 mg/L (National Academy of Science, 1982).

Asbestos fibers may be released into drinking water as aggressive (corrosive) waters dissolve the matrix of asbestos-cement pipe. Health hazards associated with the ingesting of asbestos fibers have not been confirmed. However, the presence of fibers in drinking-water supplies has been a source of concern to public officials.

The U.S. Environmental Protection Agency (USEPA) has issued regulations for several of these substances in public drinking-water supplies; the regulations include both enforceable maximum contaminant levels (MCLs) and nonenforceable secondary maximum contaminant levels (SMCLs) (U.S. Environmental Protection Agency, 1977). Selected regulations in effect at the time of the study are listed in table 1. The New Jersey Primary and Secondary Drinking-Water Criteria are the same as those of the USEPA MCLs and SMCLs (New Jersey Department of Environmental Protection, 1985).

Table 1.--U.S. Environmental Protection Agency Drinking-Water Regulations for selected metals

[From U.S. Environmental Protection Agency (1977); MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; µg/L, micrograms per liter]

| Contaminant | Maximum contaminant concentration (µg/L) | Type of regulation |
|---|---|---|
| Lead | 50 | MCL |
| Cadmium | 10 | MCL |
| Copper | 1,000 | SMCL |
| Zinc | 5,000 | SMCL |
| Iron | 300 | SMCL |

Concern about corrosive ground water has mounted in the past decade, as trace-element concentrations in drinking water have been shown to exceed Federal drinking-water regulations in a number of municipalities across the nation. The USEPA has estimated that approximately 42 million people in the United States risk consuming drinking water containing concentrations of lead greater than the then proposed standard of 20 μg/L (micrograms per liter) (Levin, 1986). (More recently, the USEPA has changed the MCL of 50 μg/L for lead to an action level of 15 μg/L (U.S. Environmental Protection Agency, 1991)). Recently enacted amendments to the Safe Drinking Water Act of 1986 have (1) banned the use of lead in the construction of public water-supply systems and (2) mandated the identification of corrosive water supplies. The use of solder containing more than 0.2 percent lead in potable water systems has been banned in New Jersey as of February 2, 1987 (New Jersey Register, 1987). Further, the USEPA proposed a ban on the use of asbestos-cement pipe and fittings (U.S. Water News, 1986).

This study was conducted in cooperation with the New Jersey Department of Environmental Protection and Energy to assist the State of New Jersey in identifying corrosive waters under the provisions of the Safe Drinking Water Act Amendments of 1986.

## Purpose and Scope

This report presents the results of an investigation of the extent of corrosive ground water in the unconfined Kirkwood-Cohansey aquifer system in the New Jersey Coastal Plain. Water-quality data collected during 1951-87 at 370 wells screened in the Kirkwood-Cohansey aquifer system were retrieved from the U.S. Geological Survey's WATSTORE data base. The majority of these data were collected after 1980. Two corrosion indices, the Aggressive Index and the Larson Index, were calculated for water from the 370 wells. The Langelier Saturation Index and the Riddick Corrosion Index also were calculated, but for a smaller number of wells, because the necessary chemical data were lacking in a number of cases.

Prior to this study, analyses of trace elements in tap water were performed on samples from 32 homes with wells tapping the Kirkwood-Cohansey aquifer system in Ocean and Atlantic Counties (Kish and others, 1987). Similar measurements were made of samples collected during this study from 10 homes in Franklinville, Gloucester County. The results of the tap-water studies are discussed in this report.

This report also discusses the relations of corrosive ground water, as estimated by the corrosion-index values, to ground-water chemistry and to the natural and anthropogenic factors that affect ground-water chemistry. Precipitation chemistry, topography, soils, geology, aquifer properties, and land use are considered.

## Well-Numbering System

The well-numbering system used on the maps (pl. 1) and tables in this report is based on the numbering system used by the U.S. Geological Survey in New Jersey since 1978. The well number consists of a county code number and a

sequence number assigned to the well within the county. Code numbers for the New Jersey Coastal Plain counties included in this report are listed below:

| | | | |
|---|---|---|---|
| 01 | Atlantic | 15 | Gloucester |
| 05 | Burlington | 25 | Monmouth |
| 07 | Camden | 29 | Ocean |
| 11 | Cumberland | 33 | Salem |

For example, well number 050609 represents the 609th well inventoried in Burlington County.


## Acknowledgments

The encouragement and assistance of Robert T. Mueller (New Jersey Department of Environmental Protection and Energy) is gratefully acknowledged. Thanks are due to Deborah Maher (Atlantic County Health Department) for providing tap-water data, and to Michael J. Barcelona and Michael Schock (Illinois Department of Energy and Natural Resources, State Water Survey Division) for supplying Langelier-Saturation-Index constant values. The authors are grateful for the cooperation of the homeowners in Franklinville, Gloucester County, in collecting tap-water samples.


# DESCRIPTION OF THE STUDY AREA

The study area for this report encompasses most of southern New Jersey, exclusive of Cape May County, and includes all of Atlantic, Cumberland, and Ocean Counties, southern Monmouth County, and much of Burlington, Camden, Gloucester, and Salem Counties. The study area is located entirely within the Atlantic Coastal Plain physiographic province (fig. 1), which is an area of predominantly sandy soils, low relief, and gently sloping hills. The Fall Line separates the Coastal Plain from the Piedmont physiographic province. The middle to late Tertiary sediments and hydraulically connected Pleistocene sediments that comprise the Kirkwood-Cohansey aquifer system crop out within the study area.

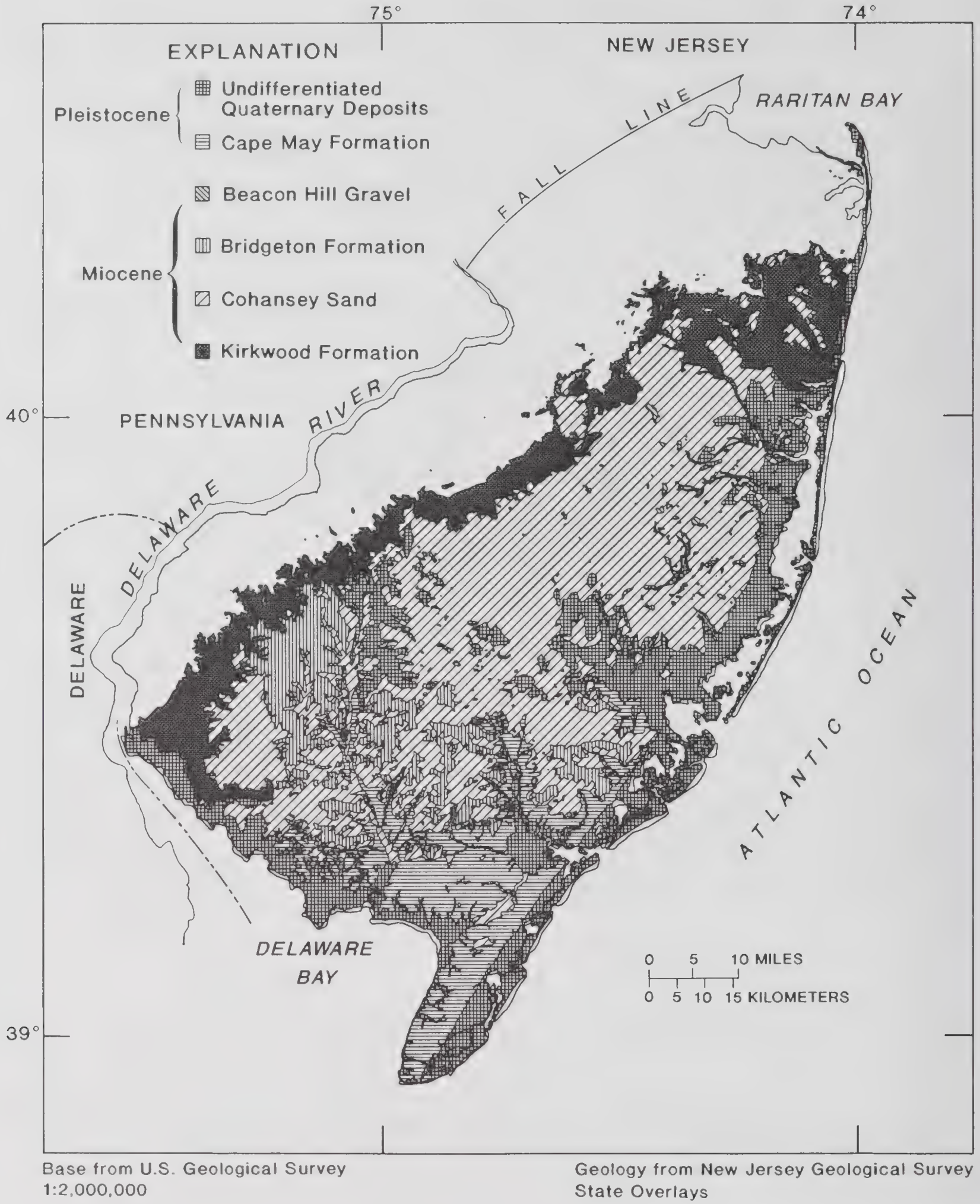
## Geology

The unconsolidated sediments of the New Jersey Coastal Plain form a seaward-thickening wedge which is composed of alternating sequences of gravel, sand, silt, and clay (figs. 2 and 3). Ranging in age from Cretaceous to Quaternary, the oldest (Cretaceous) Coastal Plain deposits are interpreted as mainly marine and deltaic in origin, with the youngest (Quaternary) having been deposited by fluvial and aeolian processes (Rhodehamel, 1979a). The sedimentary wedge unconformably overlies metamorphic rocks of Precambrian age, as well as Triassic and Jurassic sedimentary rocks.

This report is concerned only with the uppermost of the Coastal Plain sediments which comprise the unconfined Kirkwood-Cohansey aquifer system. These include the Kirkwood Formation, the Cohansey Sand, the Beacon Hill Gravel, the Bridgeton Formation, and parts of the Cape May Formation (Rhodehamel, 1973).

Base from U.S. Geological Survey
1:250,000 quadrangles

Figure 1.--Location of the study area.




Base from U.S. Geological Survey
1:2,000,000

Geology from New Jersey Geological Survey
State Overlays

Figure 2.--Geologic map of the Miocene through Pleistocene sediments that crop out in the study area.

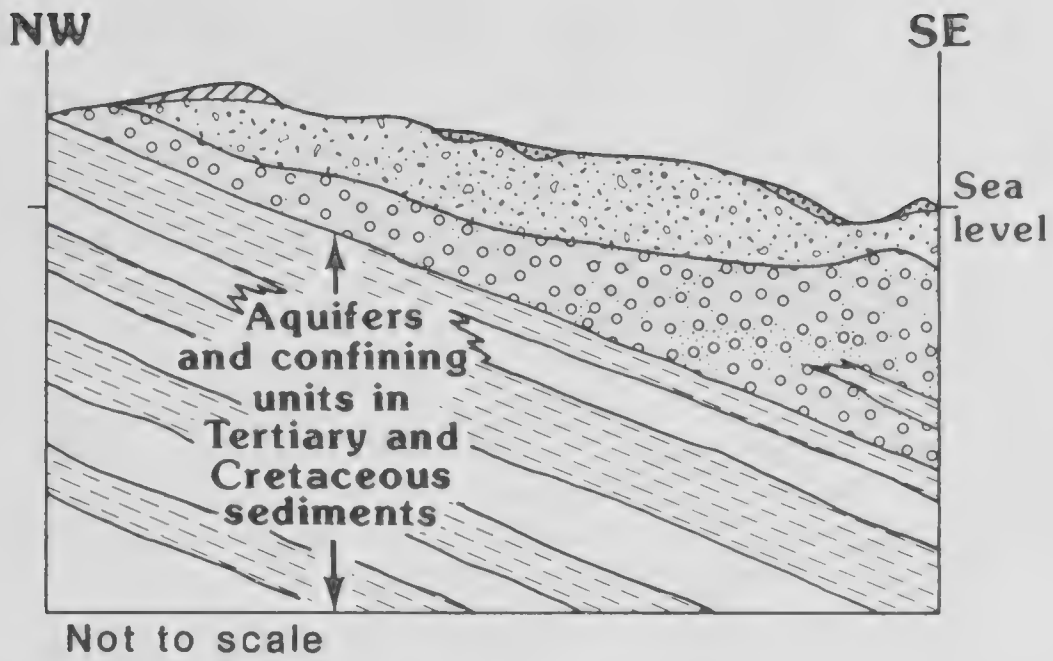



Figure 3.--Generalized northwest-southeast hydrogeologic cross-section through the study area.

The oldest unit included in the Kirkwood-Cohansey aquifer system is the Kirkwood Formation of Miocene age. The Kirkwood is composed largely of thick beds of micaceous, very fine quartz sand which interfinger with layers of carbonaceous clayey silt (Owens and Sohl, 1969). Thick interbedded clay units are found near the coastline (Zapecza, 1989). The sediments of the Kirkwood Formation overlie a sequence of sands and clays, including glauconitic sands, that range in age from Cretaceous through early Tertiary.

The Cohansey Sand, which overlies the Kirkwood Formation, also is of Miocene age, and is the most extensive surficial deposit in the New Jersey Coastal Plain. The lithology of the Cohansey Sand, although variable, is predominantly yellow, limonitic, poorly sorted quartz sand. Clay lenses, and minor beds of silty and clayey sand also are present. The Cohansey Sand also contains ironstone pebbles and minor amounts of feldspar, vein quartz, and chert. Structures within the Cohansey Sand include parallel bedding and cross-stratification (Rhodehamel, 1979a). Within the study area, the Cohansey Sand and the Kirkwood Formation together range in thickness from a featheredge at the western boundary of the outcrop of the Kirkwood Formation to more than 500 ft (feet) downdip in Cumberland County (Zapecza, 1989, pl. 24).

The Tertiary Beacon Hill Gravel and Bridgeton Formation are fluvial deposits of Miocene age (Owens and Minard, 1979) that form a discontinuous veneer over the Cohansey Sand (Rhodehamel, 1973). Although not areally extensive, the coarse-grained sands and gravels of both formations are relatively thick. The Beacon Hill Gravel can be up to 40 ft thick, and the Bridgeton Formation up to 50 ft thick (Zapecza, 1989, p. 19).

The Quaternary Cape May Formation, which crops out discontinously in the southern part of the New Jersey Coastal Plain, is of Pleistocene age, and is composed of sands, gravels, and some clays. In the Cape May peninsula, the Cape May Formation has been divided into four environmental facies: deltaic sand, marine sand, estuarine clay, and estuarine sand (Gill, 1962); elsewhere, the sediments of the Cape May Formation are undifferentiated.

## Hydrology of the Kirkwood-Cohansey Aquifer System

The Kirkwood-Cohansey aquifer system underlies approximately 3,000 square miles of the New Jersey Coastal Plain. Although confined by overlying Pleistocene deposits in the Cape May peninsula, the Kirkwood-Cohansey aquifer system is primarily a water-table aquifer because, throughout most of its extent, Pleistocene deposits are hydraulically connected to the older sediments. Near Atlantic City, however, a thick, diatomaceous clay unit confines the Atlantic City 800-foot sand which is part of the Kirkwood Formation[1]. Updip from the confining unit above the Atlantic City 800-foot sand, the base of the unconfined aquifer system is more than 350 ft below sea level, whereas, near the coast, the base of the unconfined part of the aquifer system is only about 160 ft below sea level (Zapecza, 1989, p. 33). Figure 4

---

[1] Data for water from the Atlantic City 800-foot sand are not included in this report because the chemistry of the water in the confined part of the system differs substantially from that of the water in the unconfined part of the system. Data for water from the confined Cohansey Sand in the Cape May peninsula also are excluded, for the same reason.

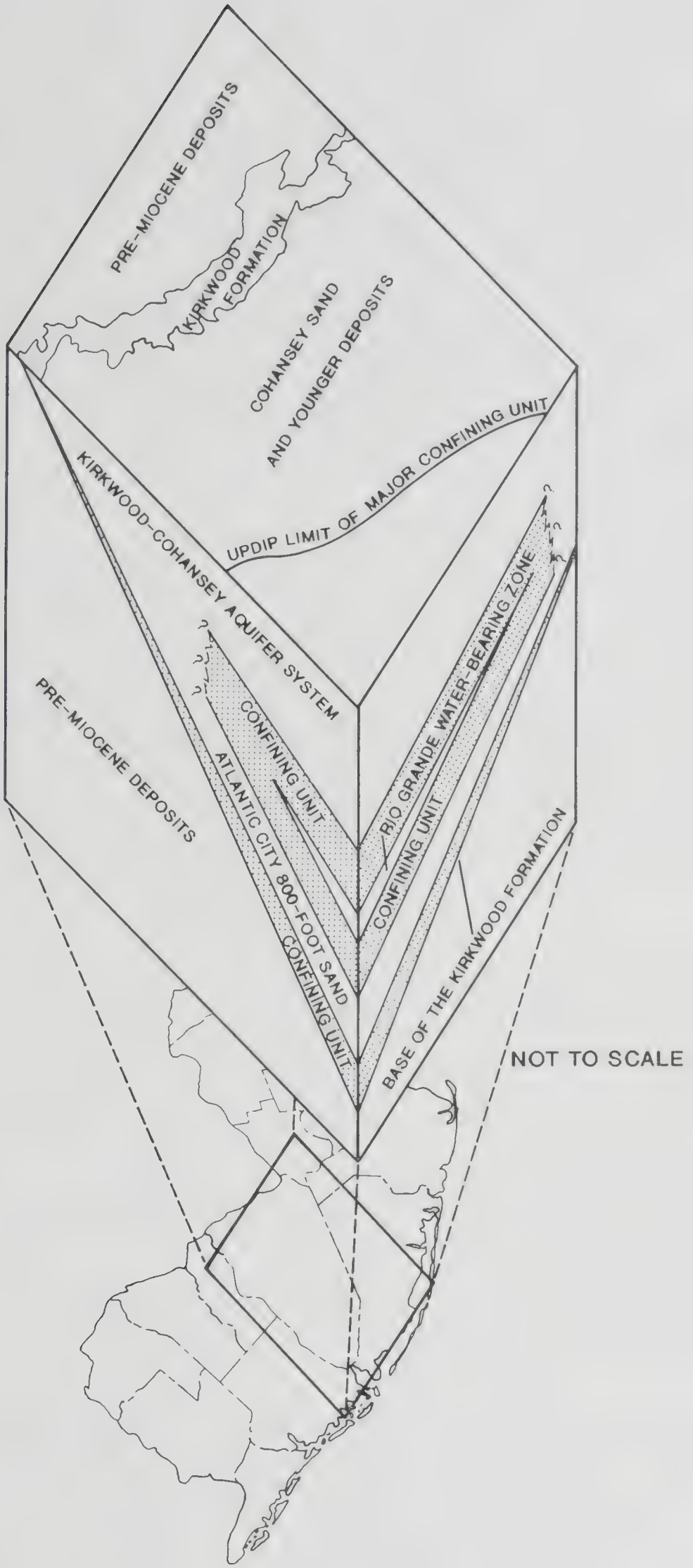



Figure 4.--Presumed stratigraphic relations between the Kirkwood-Cohansey aquifer system and the Atlantic City 800-foot sand. (Modified from Zapecza, 1989, fig. 5.)

shows diagrammatically the relations of the unconfined and confined parts of the aquifer system. A confining layer separates the Kirkwood-Cohansey aquifer system from the underlying Piney Point aquifer. This latter aquifer does not crop out in New Jersey because the sediments pinch out updip. Therefore, the Piney Point aquifer is present only in the subsurface in New Jersey.

The late Miocene Beacon Hill Gravel and Bridgeton Formation and a portion of the Pleistocene Cape May Formation also are locally connected hydraulically to the aquifer system (Zapecza, 1989, p. 19). However, in the Cape May peninsula, the upper part of the Cape May Formation is considered to be a separate aquifer. The estuarine clay acts as a confining layer between the overlying deltaic and marine sands and the estuarine sand, which is hydraulically connected to the confined Cohansey Sand (Zapecza, 1989, p. 33).

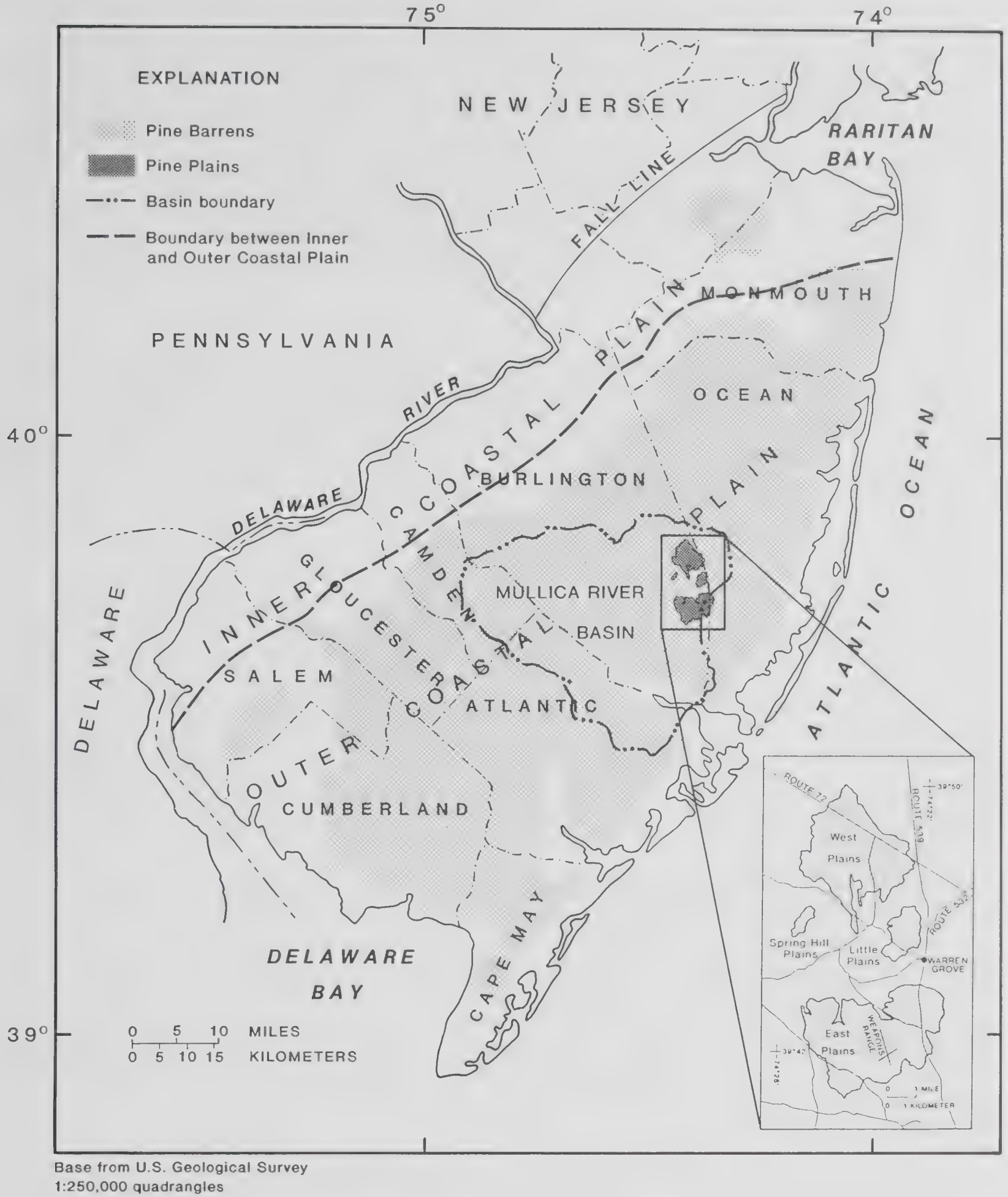
Recharge to the unconfined Kirkwood-Cohansey aquifer system is primarily through precipitation. Although most recharge enters local flow systems that discharge to nearby streams, some recharge in upland areas enters deeper flow systems in the basal Cohansey Sand and Kirkwood Formation sediments. Recharge in upland areas occurs in the west-central and northern parts of the study area, whereas discharge from the deeper flow systems is along the coast, and intermittently along the outcrop area of the Kirkwood Formation (Mary Martin, U.S. Geological Survey, oral commun., 1988). Simulated potentiometric surfaces for the Kirkwood-Cohansey aquifer system and the underlying Piney Point aquifer indicate that, beneath the Mullica River basin (fig. 5), water moves upward through the confining unit above the Piney Point aquifer into the Kirkwood-Cohansey aquifer system (Martin, 1990, figs. 48 and 50).

## Soils and Vegetation

Soil scientists have divided the Coastal Plain of New Jersey into two regions: the inner Coastal Plain and the outer Coastal Plain (Markley, 1971, fig. 4). Soils of the inner Coastal Plain coincide geologically with the outcrop of unconsolidated sediments that are older than the Kirkwood Formation and Cohansey Sand. The soils of the outer Coastal Plain generally coincide with outcrop areas of the Kirkwood Formation and the Cohansey Sand.

The soils of the outer Coastal Plain typically are sands or sandy loams. These soils range from strongly to extremely acidic, and they have low fertility (Markley, 1979). Only small amounts of clay are present, and the cation-exchange capacity of the soils is low (Douglas and Trela, 1979). Soils in upland areas tend to be well- to excessively drained. Lowland soils, although sandy, generally are poorly drained, and commonly contain a larger percentage of organic material than do upland soils (Markley, 1979, p. 84-85).

The vegetation supported by these soils includes southern white cedar, red maple, and black gum in the lowlands, and pines and oaks in the uplands (McCormick, 1979). Much of the study area is forested; this extensive area is known as the Pine Barrens of New Jersey. An upland area of dwarf pitch pines is known as the Pine Plains (fig. 5).




Base from U.S. Geological Survey
1:250,000 quadrangles

Figure 5.--Locations of outer Coastal Plain, inner Coastal Plain, Mullica River basin, Pine Barrens, and Pine Plains. (Modified from Stone, 1911; McCormick, 1967 with permission of the New Jersey State Museum; Bucholz and Zampella, 1987, with permission of the New Jersey Academy of Sciences).

## Chemical Characteristics of Ground Water

Water-quality data collected from 1951 through 1987 indicates that ground water in the unconfined Kirkwood-Cohansey aquifer system generally is acidic, with a median pH of 5.1. Higher pH values are found in some coastal[2] areas where ground water is more saline (Harriman and Sargent, 1985), whereas the lowest values (less than 5 pH units) generally are found inland. Isolated instances of pH values greater than 7.0 are found in water from wells in some northern and western parts of the study area, where the Kirkwood Formation crops out or is near the surface, and in a few deep wells that tap the Kirkwood Formation part of the aquifer system in the central part of the Coastal Plain.

Alkalinity concentrations tend to be small, with a median value of 3.0 mg/L as calcium carbonate. In some areas, negative alkalinities are found. (Negative alkalinities are measured when the acidity of a given water sample exceeds the acid-neutralizing capacity of the water.) Alkalinity concentrations tend to be larger (in some cases greater than 80 mg/L) in water from wells in coastal areas, and also are found to be larger than 3.0 mg/L in water from some wells that tap the Kirkwood Formation part of the aquifer system.

Concentrations of dissolved solids tend to be smaller than 100 mg/L in water from the Kirkwood-Cohansey aquifer system. The smallest dissolved solids concentration for the sample set of 370 wells is 8 mg/L. Dissolved solids concentrations are larger than 100 mg/L in some coastal areas; a maximum concentration of 668 mg/L is reported for water from a well in Ocean County. Water from the aquifer system generally is soft. A median value for calcium-hardness concentration (calcium concentration expressed as calcium carbonate) is 3 mg/L. Calcium-hardness concentrations in water from wells far from the coast commonly are smaller than 1 mg/L but tend to be larger in water from wells near the coast and from wells located in agricultural areas in Cumberland, Gloucester, and Salem Counties.

Chloride concentrations generally are small in water from the unconfined part of the Kirkwood-Cohansey aquifer system, with a median value of 5.4 mg/L. In water from wells in relatively undeveloped areas (population less than 5 persons per acre), chloride concentrations typically are smaller than 5 mg/L. However, slightly elevated chloride concentrations (8 to 42 mg/L) are found in water from wells adjacent to major roadways and in some wells in urban and agricultural areas. Chloride concentrations also are elevated in water from a number of coastal wells, where concentrations have been found to exceed the USEPA SMCL and the New Jersey Secondary Drinking Water Criterion of 250 mg/L in some water samples.

The median sulfate concentration in water from the Kirkwood-Cohansey aquifer system is 5.5 mg/L, and concentrations are smaller than 5 mg/L in water from wells in relatively undeveloped areas. Sulfate concentrations tend to be elevated in water from wells in some coastal areas in Ocean County.

---

[2] In this report, the term "coastal" means a strip of land approximately 5 miles wide that extends along the Atlantic Coast of southern New Jersey and continues along the Delaware Bay.

Slightly elevated sulfate concentrations (8 to 18 mg/L) have been found to be present in shallow ground water (less than 30 ft below land surface) underlying and discharging to forested wetlands in the Lebanon and Wharton State Forests. Sulfate concentrations (20 to 50 mg/L) are moderately elevated in water from wells in urban areas such as Lakewood and Vineland, and range between 20 and 110 mg/L in agricultural areas in Gloucester, Salem, and Cumberland Counties. Sulfate concentrations are found to decrease with depth of well screen in ground water from Burlington, Camden, and Cumberland Counties. Table 2 summarizes descriptive statistics for pH, calcium hardness, alkalinity, chloride, and sulfate, that were derived from the historical water-quality data for 370 wells. Only the most recent analysis for each well was considered in deriving these statistics; the water samples were collected between 1951 and 1988.

Table 2.--Median values, ranges, and selected interquartile ranges for chemical properties and constituents of ground water from the unconfined Kirkwood-Cohansey aquifer system

[Number of wells sampled was 370; mg/L, milligrams per liter; <, less than; Q1, first quartile; Q3, third quartile]

| Statistical measure | pH (units) | Calcium hardness (mg/L as $CaCO_3$) | Alkalinity (mg/L as $CaCO_3$) | Chloride (mg/L) | Sulfate (mg/L) |
|---|---|---|---|---|---|
| median | 5.1 | 3.0 | 3.0 | 5.4 | 5.5 |
| minimum | 3.8 | <.1 | <.5 | .1 | <.1 |
| maximum | 8.2 | 195 | 88 | 300 | 160 |
| Q1-Q3 | 4.8 - 5.6 | 1.0 - 9.0 | 1.0 - 5.0 | 3.6 - 10 | 1.8 - 10 |

## METHODS AND DATA SOURCES

In order to provide an estimate of the corrosiveness of a given water sample, corrosion indices were calculated from water-quality data. Four corrosion indices (the Langelier Saturation Index, the Aggressive Index, the Larson Index, and the Riddick Corrosion Index) developed for use by the water-treatment community were chosen for use in the current study, and are discussed in detail in the following section of this report.

Previously collected water-quality data for 370 wells that tap the unconfined Kirkwood-Cohansey aquifer system were used to calculate the four corrosion indices. The wells were sampled from 1951 through 1987; however, most (87 percent) of the data were collected from 1980 through 1987. Information on well construction and water-quality data from sampling during this latter period are found in Harriman and Voronin (1984), Harriman and Sargent (1985), Knobel (1985), Lord and others (1990), Barton and others (in press), and P.J. Lacombe and Robert Rosman (U.S. Geological Survey, written commun., 1989). Data used to calculate the indices were retrieved from the

WATSTORE data base maintained by the U.S. Geological Survey. Chemical data that failed the cation/anion balance, based on the criteria of Friedman and Erdmann (1982, p. 104), were excluded from the calculations by using a quality-assurance screening program (D.A. Harriman, U.S. Geological Survey, written commun., 1987).

All corrosion indices calculated for this study are a function of alkalinity. The detection limit for all but a few analyses was given as 1 mg/L. If alkalinity values were reported as less than 1 mg/L (< 1 mg/L), the value of 1 mg/L was used in the index calculations. Thus the index values derived for well water with extremely small alkalinity concentrations are higher than the actual values of the Aggressive and Langelier Indices, and lower than the actual values of the Riddick and Larson Indices, indicating less corrosive water than actually is the case. The Larson Index, which is a ratio, is affected the most by this method of treating censored data. Field measurements of pH and alkalinity were used in index-calculations; laboratory measurements of pH and alkalinity were used only if field data were missing from the analysis. A check of existing field and laboratory data indicated that there was generally good agreement between values, and that, therefore, the use of laboratory values for pH and alkalinity concentrations would not introduce serious error into the indices calculated.

Chemical data were not available in all cases to calculate all four indices for each well. However, at least two indices were calculated for each well. Of those two indices (the Aggressive Index and the Larson Index), the Aggressive Index was judged to estimate more accurately the corrosiveness of water from the Kirkwood-Cohansey aquifer system. The Aggressive Index was chosen to represent the corrosiveness of water on maps because (1) it could be calculated for all the samples in the data set, (2) it fluctuated only slightly through time in most areas, (3) it was less dependent on depth than was the Larson Index, and (4) the values of the Aggressive Index were less severely affected than those of the Larson Index if the alkalinity detection limit was substituted for a concentration less than the detection limit. Furthermore, because Larson's experiments used water with dissolved-solids concentrations ranging from about 250 to about 1,000 mg/L, the Larson Index is not designed for water with low dissolved-solids concentrations (Singley and others, 1985). Water with dissolved-solids concentrations of less than 250 mg/L is found throughout much of the Kirkwood-Cohansey aquifer system, therefore, the Larson Index probably is applicable only to water from parts of the aquifer system where dissolved-solids concentrations are greater than 250 mg/L.

Maps showing well locations and values of the Aggressive Index were constructed using geographic information system software (pl. 1). The most recent data for each well (samples collected between 1951 and 1988) were used in the calculations of the index values shown on the maps in order to represent the most current data available. Thirteen wells from the initial data set of 370 wells are not shown on the maps; these are the deepest of those wells installed as nested piezometers. Where more than one well was located at the same map coordinates, only the shallowest well was plotted on the maps. Thus, the maps show data for 357 domestic, observation, and municipal wells. Well types are not differentiated on plate 1.

In order to evaluate the reliability of the corrosion indices as estimators of ground-water corrosiveness, data from previous studies of trace-metal leaching by tap water (Kish and others, 1987; Deborah Maher, Atlantic County Health Department, written commun., 1987) were examined, and an additional study of tap water was conducted during the course of this investigation. The tap-water samples were collected by the homeowner following instructions based on a protocol established by Karalekas and others (1978).

As in the previous study by Kish and others (1987), the participating Gloucester County homeowners were instructed to use no water during the night, and then to fill two bottles from the kitchen or bathroom cold-water tap with the first morning water. One sample bottle was an acid-rinsed 250-mL (milliliter) polyethylene bottle for metals analysis; the other was a deionized-water-rinsed 250-mL polyethylene bottle for pH and specific-conductance determinations. After 15 minutes of running the water, a set of three bottles was filled (one acid-rinsed bottle for metals analysis, two deionized-water-rinsed bottles, one for pH and specific conductance measurements and one for sulfate, chloride, and alkalinity determinations). All sample bottles were retrieved by U.S. Geological Survey personnel within about 2 hours of sampling, and the bottles for metals analysis were acidified with nitric acid to a pH of less than 2[3]. A duplicate sample was collected from one home 1 week after the original sample was collected.

Samples from the 10 homes in Franklinville, Gloucester County, were analyzed for metals and major cations by inductively coupled plasma spectroscopy at the U.S. Geological Survey National Water-Quality Laboratory, in Arvada, Colorado. Alkalinity was determined by fixed-endpoint titration; chloride, by colorimetry; and sulfate, by the turbidimetric method.

## CORROSION

Corrosion is "the deterioration of a substance or its properties due to a reaction with its environment" (Singley and others, 1985, p. 6). The environment with which this report is concerned is that of ground water in an unconfined aquifer system.

### Materials Affected

Ground water, if used as a water source, comes in contact with the structural materials of water-distribution systems. These materials include copper, brass, zinc, lead, cast iron, galvanized iron, steel, and asbestos-cement. Various manmade structures such as bridge piers and below-ground storage tanks also may come in contact with ground water.

Physical and chemical reactions can extract metals and asbestos fibers from the distribution system, and increase the concentrations of these substances in drinking-water supplies.

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[3] An interval of 2 to 3 hours between time of sample collection and time of acidification was not considered to compromise the accuracy of trace-metal analysis. Miller and others (1985) reported that acidification of water samples can be delayed for 14 days after collection without substantially affecting lead concentration.

## Physical Erosion and Chemical Reactions

The physical action of water with high flow velocity can promote corrosion in pipe, particularly at elbows and joints. Corrosion can occur because the action of the water causes erosion of a protective film of mineral deposits on the pipe's inner surface. The erosion may be caused by suspended particles, but also may result from rapidly flowing water removing protective deposits or preventing their formation (Schock and Neff, 1982).

Metallic corrosion occurs when electrons are released by oxidation at an anode and are consumed at a cathode through a reduction. The medium for the flow of current is the water, in which ions are present. Oxidation of metal produces ions, which can then, in the appropriate chemical environment, remain as dissolved species in the water. The relative tendencies for metals to corrode are controlled by their electrode potentials. Figure 6 illustrates the metallic corrosion process, using iron in contact with ground water as an example. Fe, which is elemental iron, loses two electrons ($e^-$) to form $Fe^{2+}$. $Fe^{2+}$ reacts with water to produce iron hydroxide ($Fe(OH)_2$) and $H^+$. $H^+$ is reduced by the electrons, and forms hydrogen gas ($H_2$) at the electrode. In an oxygenated system, $Fe^{2+}$ is oxidized to $Fe^{3+}$ and forms $Fe(OH)_3$.

Although the example shown in figure 6 illustrates the oxidation of iron as an inorganic process, bacteria typically are present to catalyze reactions; bacteria, therefore, can be participants in the corrosion process. Dissolved oxygen is a common and important oxidant; other oxidizing agents such as disinfectants, free chlorine, chloramines, and ozone can promote the corrosion process (Schock and Neff, 1982).

In cases where two different metals are in contact with one another, a galvanic cell is created, where one metal acts as an anode and the other acts as a cathode. The metal that is the more easily oxidized of the two is the anode, and dissolution of that metal occurs. In general, copper-bearing metals tend to act as cathodes, thereby enhancing the dissolution of other metals that act as anodes (Schock and Neff, 1982). The diagram shown in figure 7 illustrates a galvanic cell between copper pipe and lead solder. Lead is oxidized, and lead ions ($Pb^{2+}$) go into solution. Cupric ions ($Cu^{2+}$) are reduced and plate out as metallic copper at the anode.

Temperature affects a variety of chemical reactions that cause or are associated with corrosion. These reactions include the dissolution of materials such as asbestos-cement matrix, the dissolution or precipitation of calcium carbonate, and electrochemical reactions involving metals. The rates of corrosion reactions increase with water temperature, and metals typically are more soluble in hot water than in cold. However, calcium carbonate is less soluble in hot water than in cold and can readily form a protective coating on pipes transporting hot water.

Electrode potentials may change as a function of temperature. At temperatures in excess of 60 °C (140 °F), which could be found in hot tap-water pipes, the electrode potential of the zinc/iron couple changes, and zinc may become the cathode, thus accelerating the corrosion of iron (Singley and others, 1985).

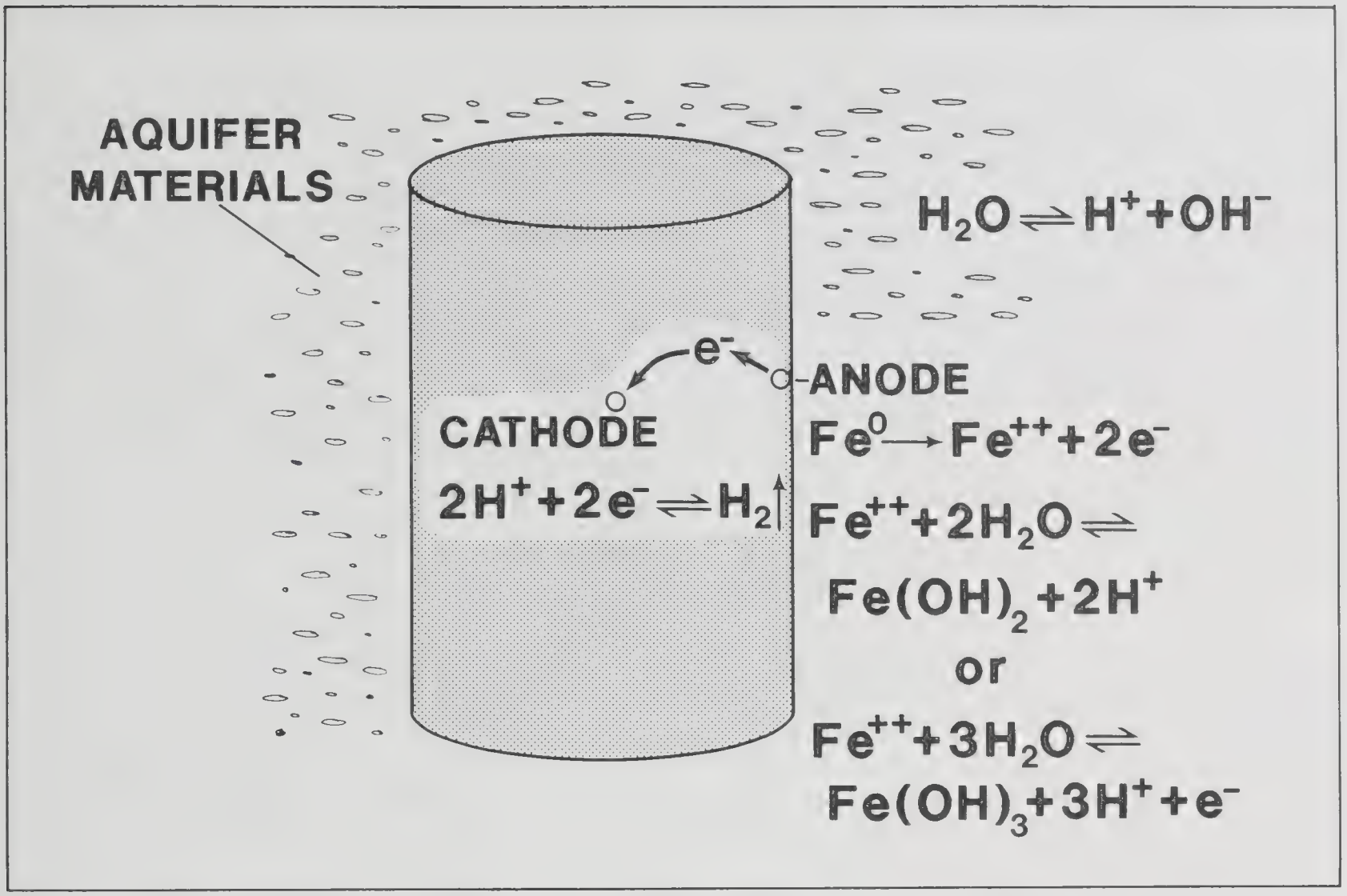



Figure 6.--Diagrammatic representation of iron (Fe) in contact with ground water, showing simplified anode and cathode reactions.

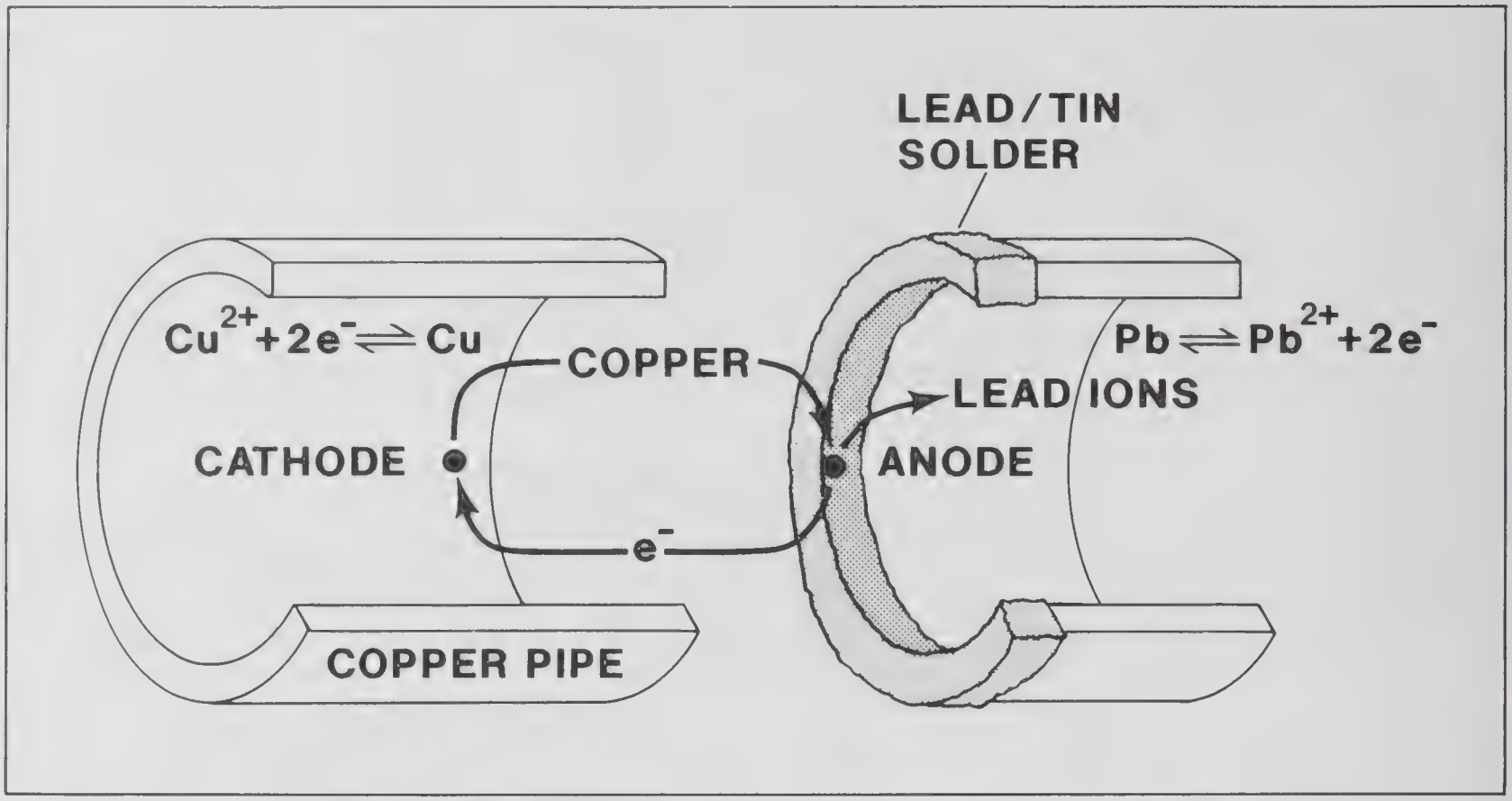



Figure 7.--Diagrammatic representation of a galvanic cell between copper pipe and lead solder.

Dissolved oxygen acts as an electron acceptor in metallic corrosion reactions. Further, oxygen reacts with hydrogen released at the cathode, permitting the corrosion reaction to continue by removing the hydrogen shield. Ultimately, however, protective metal-oxide films can form as oxygen reacts with metal surfaces (Singley and others, 1985). Nitrate ion has been implicated in the corrosion of ferrous materials, where it reacts with hydrogen at the cathode in a manner similar to oxygen (Singley and others, 1985).

A large concentration of dissolved solids implies a large ion concentration in water, which causes the water to be highly conductive. In general, the higher the conductivity, the more easily the water conducts a current which promotes metallic corrosion (Singley and others, 1985, p. 16). However, large concentrations of some ions can promote the precipitation of protective films. Hard waters tend to inhibit corrosion (Singley and others, 1985, p. 16), and experimental work indicates that the solubility of lead, for example, decreases as calcium concentrations increase (Moore, 1973).

The pH and alkalinity of water determine whether various protective films are precipitated or dissolved, and also whether the metals present are in the form of free ions or hydroxyl complexes (Singley and others, 1985; Schock and Neff, 1982). Acidic waters tend to dissolve carbonate films, and metals will be present as free ions. Alkalinity, a measure of a water's capacity to neutralize acids, affects corrosion reactions in several ways. Bicarbonate alkalinity can neutralize both acids and bases, buffering the water against changes in pH. Bicarbonate and carbonate alkalinity can control calcium concentrations, and thus reduce the dissolution of cement materials in contact with the water. Waters with moderate carbonate alkalinity tend to precipitate various carbonate minerals that can shield pipe surfaces from corrosive attack (Singley and others, 1985). However, the solubility of lead increases in waters with high carbonate alkalinity concentrations (greater than 100 mg/L as calcium carbonate) at pH values of about 8 to 8.5 (Schock and Gardels, 1983).

The presence of chloride and sulfate in water promotes corrosion and pitting of iron and copper. Because both ions form strong acids, they tend to increase the acidity of water. Also, chloride and sulfate probably increase corrosion rates by increasing the conductivity of the water. Sulfate may inhibit the formation of protective films by ion-pairing with calcium and magnesium (Schock and Neff, 1982). Free chlorine in chlorinated water supplies promotes corrosion of copper, particularly at low pH values (Atlas and others, 1982).

Other chemical compounds, which are not routinely analyzed in most water samples, can be involved in the corrosion process. Dissolved carbon dioxide, forming carbonic acid at low pH, may dissolve protective calcium carbonate or hydrated iron oxide films (Singley and others, 1985, p. 140). Schock and Neff (1982) indicate that the effects of free carbon dioxide on dissolution of metals or corrosion rate is not well understood. Hydrogen sulfide (only present under reducing conditions) can form insoluble sulfides by reacting with metal ions, and therefore, accelerating corrosion (Singley and others, 1985, p. 17).

In summary, erosion can remove protective films from pipe surfaces. High temperatures tend to accelerate the metallic corrosion process. Corrosive waters typically, although not always, are acidic, with low alkalinity and low calcium hardness concentrations. Strongly alkaline solutions also can be corrosive. Elevated concentrations of chloride and sulfate can contribute to the corrosion process. Although redox reactions can take place under anoxic conditions, the presence of dissolved oxygen is necessary to the corrosion of some metals such as copper (Singley and others, 1985), and oxygen plays an important role in many of the redox reactions involved in corrosion. Dissolved oxygen also can promote the precipitation of protective oxide films on pipe surfaces.

## Corrosion Indices

### Approach

The corrosiveness of water can be estimated by the calculation of one or more corrosion indices. A corrosion index is a mathematical formulation that is based on the concentrations of various chemical constituents and the physical properties of the water. Of the corrosion indices commonly in use, some are based on thermodynamic relations, whereas others are empirical formulations derived from experimental work.

Indices derived from thermodynamic relations typically are in the form of a saturation index (see, for example, Butler, 1982, p. 155, fig. 5-17) for a solid (SI)--

$$SI = \log (\text{ion activity product}/\text{solubility constant } K). \quad (1)$$

The formulations for empirically derived corrosion indices follow no particular form.

Four indices, discussed in detail below, were used to estimate corrosiveness of ground water for the purposes of this study. Two of the indices are derived from thermodynamic relations, and two are empirically derived. The four indices calculated for the current study were selected for the following reasons. The Langelier and Aggressive Indices were chosen because they are used widely by the water-treatment community, and use of one or the other index was included in the 1980 amendments to the National Interim Primary Drinking Water Regulations in the Federal Register, August 1980. The calculations for the Langelier Saturation Index require a temperature correction; temperature data were lacking for a number of analyses in the data set, and thus this index could not be calculated for all 370 wells. The Aggressive Index is a simplification of the Langelier Index, and therefore gives similar results. The advantage of using the Aggressive Index is that its calculation requires a minimal number of chemical constituents; thus, analyses with relatively few constituents can be included in the data set. Although somewhat redundant, both the Langelier and Aggressive Indices were calculated, and the Langelier values were used to confirm the Aggressive Index values.

The Larson Index was chosen for calculation because few constituents are needed, and these constituents include chloride and sulfate. Waters containing relatively large concentrations of chloride and sulfate are encountered in parts of the Kirkwood-Cohansey aquifer system. The Larson Index was formulated from experimental work with solutions that contained relatively large concentrations of dissolved solids; therefore, it may not be applicable to the dilute waters found in many parts of the Kirkwood-Cohansey aquifer system. However, the Larson Index was calculated for all wells in the data set with the expectation that the index would provide an estimate of the corrosiveness of some, if not all, water samples.

Finally, although data on the concentrations of some chemical constituents needed to calculate the Riddick Corrosion Index commonly were not available, this index was included because it has been applied successfully to the typically soft ground waters of the eastern seaboard (Singley and others, 1985, p. 41). Dissolved-oxygen concentration is a key component of the Riddick Index calculations; another important measurement is barometric pressure, needed to calculate saturated dissolved oxygen. Such data were lacking for the majority of wells sampled. Thus, although the Riddick Index probably would have been the index best suited to describe the corrosiveness of water from the Kirkwood-Cohansey aquifer system, the limited number of wells for which it could be calculated required use of another index as the chief descriptor. Of necessity, the Aggressive Index was chosen as the chief descriptor, although it and the Langelier Saturation Index are less effective in estimating the corrosiveness of low-pH waters than in estimating that of waters with pH greater than 6.5 (Singley and others, 1985). Riddick Corrosion Index values were used to confirm the estimates given by other indices.

The formulations of the four indices all require alkalinity concentrations for calculation. As discussed previously, alkalinity concentrations less than 1 mg/L (as calcium carbonate) were reported for water from a number of wells. The index calculations were carried out by using 1 mg/L as the value for alkalinity. This practice resulted in an underestimate of the corrosiveness of water from these wells. Despite this problem, the wells and their index values were not deleted from the data set because, in some parts of the study area, the remaining data would have been insufficient to give a regional perspective on ground-water corrosiveness. In the most extreme example, 50 percent of the data for Camden County would have been deleted had these wells been deleted from the data set.

In all cases, water with very small alkalinity concentrations is estimated to be highly corrosive; thus, the underestimate of corrosiveness is only a matter of degree. In order to maintain the most complete spatial coverage of the study area, the wells that tap low-alkalinity water remain in the data set. They can be identified readily in both the data tables and the maps in this report. Alkalinity values of less than 1 mg/L are indicated with a < sign in tables 5-12; AI values that represent an underestimate of corrosiveness are indicated with an asterisk on plate 1.

Langelier Saturation Index

The Langelier Saturation Index (LSI) (Langelier, 1936), has been used widely by the water treatment community. The LSI is defined by the equation--

$$LSI = pH - pH_s, \quad (2)$$

where $pH_s = A + B - \log [Ca^{2+}] - \log [Alk]$, and both $[Ca^{2+}]$ and [Alk] (total alkalinity) are concentrations expressed as mg/L of equivalent $CaCO_3$ (Singley and others, 1985). A and B are correction factors that relate, respectively, to the temperature and dissolved-solids content of the water. On the basis of the revised calcium carbonate solubility constants of Plummer and Busenberg (1982), the values of A have been recalculated by Schock and Neff (1982). These most recent values have been used in calculations associated with the present study. Values of B were calculated using the original formulation of Larson and Buswell (1942). Values of A and B, and the derived functions used in the calculations may be found in Appendix A.

The LSI indicates whether a water is supersaturated or undersaturated with respect to calcium carbonate, and thus whether or not a protective film of calcium carbonate can be precipitated on pipe interiors. Negative LSI values indicate undersaturation with respect to calcium carbonate, an LSI value of zero indicates saturation, and values greater than zero show the water is supersaturated and calcium carbonate precipitation is favored. According to the New Jersey Secondary Drinking Water Criteria, the LSI ideally should fall within the range of -1.0 to +1.0 for drinking water (New Jersey Department of Environmental Protection, 1985).

Aggressive Index

The Aggressive Index (AI) essentially is a simplified version of the LSI, and is given by the equation--

$$AI = pH + \log [AH], \quad (3)$$

where A is alkalinity and H is calcium hardness (or concentration of calcium expressed as mg/L of equivalent $CaCO_3$) (American Water Works Association, 1977).

AI values of 12.0 or greater indicate a nonaggressive (noncorrosive) water. Values from 10.0 to 11.9 indicate that the water is moderately aggressive, and, for values less than 10.0, the water is considered to be highly aggressive. Like the LSI, the AI indicates the degree of saturation with respect to calcium carbonate, but the value of 12.0 indicates saturation for the AI; this corresponds to an ionic strength of approximately 0.01 and a temperature of approximately 14 °C (Schock and Buelow, 1981, p. 636). A value of 12.0 for the AI approximates the value of zero for the LSI.

The AI originally was formulated to determine aggressiveness (corrosiveness) of water with respect to asbestos-cement pipe used in water distribution systems (American Water Works Association, 1977), and was intended for use in waters ranging in temperature from 4 °C to 27 °C (Rossum and Merrill, 1983). The AI has been used in a nationwide survey of the corrosiveness of drinking-water supplies and generally was found to estimate adequately the aggressiveness of the waters tested (Millette and others, 1980).

Although the AI is a less rigorous expression than the LSI, the AI has been used extensively and is useful as an indicator of water quality where the data needed to calculate the LSI are not available. However, both the LSI and the AI have been found to be less effective in predicting corrosiveness for low-pH (pH less than 6.5) waters than for waters with a pH greater than 6.5 (Singley and others, 1985).

Larson Index

The Larson Index, unlike both the LSI and AI, is not related to the solubility of calcium carbonate. The Larson Index (LI) is an empirically derived ratio of specific ions which expresses the corrosive nature of a particular water sample with regard to the rate of metal corrosion. The LI is given by the equation--

$$LI = (Cl + SO_4) / Alk, \qquad (4)$$

where chloride (Cl), sulfate ($SO_4$), and total alkalinity (Alk) concentrations all are expressed as mg/L of equivalent $CaCO_3$ (Singley and others, 1985, p. 116; Larson, 1975).

An LI value greater than 0.5 indicates potential water corrosiveness (Singley and others, 1985, p. 116). The LI emerged from work with experimental solutions containing bicarbonate, chloride, and sulfate ions (Larson, 1975), and is not designed to be applied to waters with low hardness and small concentrations of dissolved solids (Singley and others, 1985, p. 116). The LI may be applicable to waters containing dissolved solids ranging from 250 to 1,000 mg/L (the range of dissolved solids in Larson's experimental solutions). As a ratio, it compares the corrosion-enhancing properties of chloride and sulfate to the corrosion-inhibiting effect of alkalinity. Schock and Neff (1982) point out that the LI is not based on chemical kinetic expressions or mass-action expressions, and does not accurately predict whether metal concentrations in drinking water will exceed drinking-water standards. Calculations for the LI are given in Appendix A.

Riddick Corrosion Index

The Riddick Corrosion Index (RCI) takes into account a larger number of factors that influence corrosion than do the previously described indices. In addition to alkalinity and hardness, the RCI includes dissolved carbon dioxide, chloride, nitrate, silica, and dissolved oxygen. The RCI, which is an empirically derived relation, is given by the equation--

$$RCI = (75 / Alk) \times [CO_2 + 1/2\ (Hardness - Alk) + Cl^- + 2N]$$

$$\times\ (10 / SiO_2) \times [(DO + 2) / Sat.\ DO], \qquad (5)$$

where $CO_2$ is the concentration of carbon dioxide in mg/L as $CaCO_3$, hardness is total hardness in mg/L as $CaCO_3$, $Cl^-$ is chloride concentration in mg/L, N is nitrate ion concentration in mg/L, $SiO_2$ is silica concentration in mg/L, DO is dissolved-oxygen concentration in mg/L, and Sat. DO is the saturated oxygen value in mg/L (Riddick, 1944). Calculations for the RCI are given in Appendix A.

## Applications

Each of the corrosion indices was developed to assess the chemical characteristics of particular types of water. The various indices are not always successful in predicting the corrosiveness of waters substantially different from those for which they were created.

Singley (1981) points out that, at present, no index exists that can be applied to all waters. Many of the indices developed evaluate the degree to which water is undersaturated, saturated, or supersaturated with respect to calcium carbonate. As such, these indices do not measure the corrosiveness of water, but rather its tendency to precipitate a film of calcium carbonate on surfaces exposed to the water. The LSI and AI belong to this group, and, although widely used, do not always accurately predict the calcium carbonate saturation state of a given water sample. The LSI is considered to reflect more accurately the saturation state of water than does the AI (Rossum and Merrill, 1983). The AI was developed to indicate the aggressiveness of water with regard to asbestos-cement pipe. Although AI values have been shown to correlate with disintegration of asbestos-cement pipe (Singley, 1981), use of the AI in this context has been called into question (Schock and Buelow, 1981). Schock and Buelow point out that asbestos-cement is not composed of calcium carbonate, and, thus, a corrosion index based on the saturation of calcium carbonate cannot predict whether asbestos-cement pipe will dissolve. Although this is true, the index has been shown to give reasonable estimates of the corrosiveness of water, nonetheless. Because the AI is a simplification of the LSI, both the AI and LSI give similar estimates of a given water's corrosiveness.

The LI was intended by Larson (1975) to be applied to hard waters with relatively high concentrations of dissolved solids (Singley, 1981; Singley and others, 1985). Furthermore, Larson designated a ratio of 0.5 as the boundary between potentially corrosive water and noncorrosive water. He did not develop a scale against which to measure corrosiveness. The literature on the corrosive tendencies of chloride and sulfate indicates that corrosion rates tend to increase with concentrations of these anions; however, LI values greater than 0.5 apparently are not meant to be interpreted to represent linear or geometric increases in corrosiveness because Larson did not interpret the values in this manner.

The RCI has been applied successfully to the soft waters of the eastern seaboard of the United States, but values of this index do not correlate well with the corrosiveness of harder waters from the middle part of the country (Singley and others, 1985). As in the case of the LI, Schock and Neff (1982) suggest that the RCI is not an accurate predictor of metal concentrations in drinking water. The ranges and interpretations of index values, and the type of water for which each index is most suitable are summarized in table 3.

## CORROSIVENESS OF GROUND WATER IN THE KIRKWOOD-COHANSEY AQUIFER SYSTEM

### Temporal Relations

Although the most recent water-quality data (1951-87) for the 370 wells were used to calculate the AI values plotted on the Coastal Plain maps (pl. 1), data from 1934 to the present were inspected to determine whether any trends in estimated ground-water corrosiveness could be discerned. Where data for a particular well spanned a number of years, corrosion indices generally changed little during the time period. Evaluation of monthly and bimonthly data for a group of shallow wells (less than 35 ft deep) in Burlington County indicated little seasonal change in AI values. Changes in AI values through time, calculated as the difference between first and last date of sampling, are given in table 4. Small changes (change in AI value less than 0.5) probably are not significant in the cases shown. (The AI values are reported to one decimal place rather than to two significant figures because rounding to whole numbers could minimize or exaggerate differences in value, depending on the direction in which the number is rounded.)

Inspection of the AI values for the 42 wells in table 4 shows that positive changes (AI values increase) are greater than negative. There are slightly more positive changes than negative. The Wilcoxon signed ranks test indicates a minor positive trend; this slight increase in AI values through time is not significant at the 0.05 level. Because many of the wells were sampled only twice, what appears to be a minor trend could represent random fluctuations rather than a steady increase or decrease through time. For three wells in Ocean County that were sampled more than twice (290533, 290513, 290480), however, relatively large changes in the AI are related to consistent increase or decrease in one or more of the chemical constituents used to calculate the AI. Two-thirds of the 42 wells in table 4 are observation wells, many of which are located in undeveloped forested areas. Anthropogenic effects on water quality may not be discernible in water underlying undeveloped areas. Changes in water from well 290513, however, may be related to its proximity to a major highway, the Garden State Parkway.

LI values were found to be more temporally variable than were AI values. Because the LI values are ratios, larger variations in LI value than in AI value are, in part, a function of the index formulation. Chloride and sulfate concentrations in samples from the same 42 wells listed in table 4 tended to vary over time, but no consistent trend was observed for either ion. Chloride concentrations in water from well 290521 increased substantially from September 1950 to September 1981. Three analyses give concentrations of 9.8, 13, and 90 mg/L. The increase in chloride concentration is likely to be related to saltwater intrusion; this public-supply well is located on a barrier beach along the Atlantic Coast of New Jersey. Increases in chloride concentrations have been monitored in wells along the Atlantic Coast, but many

Table 3.--Ranges and interpretations[1] of corrosion-index values

[>, greater than; <, less than; =, equal to; mg/L, milligrams per liter]

| Index | Range of values[2] | Interpretation | Appropriate water type |
|---|---|---|---|
| Langelier | LSI > 0 | Supersaturated (noncorrosive) | Best results with |
| | LSI = 0 | Saturated (noncorrosive) | water of pH |
| | LSI < 0 | Undersaturated (corrosive) | greater than 6.5 |
| Aggressive | AI < 10.0 | Highly aggressive (corrosive) | Same as Langelier |
| | AI=10.0-11.9 | Moderately aggressive | Saturation Index |
| | AI > 12.0 | Non-aggressive (noncorrosive) | |
| Larson | LI > 0.5 | Potential for corrosiveness exists | Hard waters with concentration of dissolved solids 250 mg/L |
| Riddick | RCI = 0-5 | Extremely noncorrosive | Soft waters |
| | RCI = 6-25 | Noncorrosive | |
| | RCI = 26-50 | Moderately corrosive | |
| | RCI = 51-75 | Corrosive | |
| | RCI = 76-100 | Very corrosive | |
| | RCI = 101+ | Extremely corrosive | |

[1] The terms "aggressive" and "corrosive" are used interchangeably in the literature to describe this characteristic of water. In this report, "corrosive" will be used henceforth. Modifiers such as "very" and "highly" also are used interchangeably in the literature. The term "highly" will be used in this report to indicate water with an AI value of less than 10.0.

[2] LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; RCI, Riddick Corrosion Index.

Table 4.--Changes in Aggressive Index values over time

[AI, Aggressive Index; change in AI value calculated as the difference between AI values from the earliest date of sampling and the most recent date of sampling; data are sorted by date of first sampling for each county; years of record are rounded to the first decimal place, and are approximate]

| Well number | Date of sampling | AI value | Date of sampling | AI value | Change in AI value | Period of record (years) | Number of samples |
|---|---|---|---|---|---|---|---|
| Atlantic County | | | | | | | |
| 010377 | 12/20/57 | 5.6 | 04/24/69 | 6.6 | +1.0 | 11.4 | 2 |
| 010387 | 10/18/61 | 6.6 | 06/21/84 | 6.7 | +0.1 | 22.7 | 2 |
| 010229 | 10/17/63 | 8.7 | 04/24/69 | 11.7 | +3.0 | 5.4 | 2 |
| 010353 | 04/22/64 | 7.0 | 08/20/68 | 7.0 | 0 | 4.3 | 2 |
| 010575 | 04/28/64 | 7.0 | 10/17/85 | 7.5 | + .5 | 21.5 | 2 |
| 010611 | 09/26/85 | 5.4 | 07/23/87 | 5.8 | + .4 | 1.8 | 2 |
| 010290 | 10/01/85 | 4.4 | 07/02/87 | 4.4 | 0 | 1.8 | 2 |
| Burlington County | | | | | | | |
| 050769 | 03/12/58 | 5.3 | 08/13/58 | 6.3 | +1.0 | .4 | 2 |
| 050029 | 08/31/61 | 6.7 | 09/07/84 | 7.8 | +1.1 | 23.0 | 3 |
| 050408 | 09/06/63 | 7.4 | 06/01/83 | 7.9 | + .5 | 19.7 | 2 |
| 050409 | 09/09/63 | 5.8 | 09/06/84 | 5.4 | - .4 | 21.0 | 3 |
| 050415 | 02/16/78 | 5.6 | 04/15/85 | 5.7 | + .1 | 7.2 | 2 |
| 050399 | 02/17/78 | 6.5 | 04/12/85 | 6.1 | - .4 | 7.2 | 2 |
| 050454 | 03/01/78 | 8.4 | 09/28/83 | 8.5 | + .1 | 5.6 | 2 |
| 050455 | 03/01/78 | 4.8 | 09/28/83 | 5.8 | +1.0 | 5.6 | 2 |
| 050019 | 03/02/78 | 4.9 | 05/13/85 | 5.4 | + .5 | 7.2 | 3 |
| 050482 | 03/02/78 | 4.9 | 09/28/83 | 4.7 | - .2 | 5.6 | 2 |
| 050418 | 03/30/78 | 4.3 | 04/15/85 | 4.9 | + .6 | 7.0 | 3 |
| 050612 | 04/05/78 | 5.8 | 07/19/84 | 5.8 | 0 | 6.3 | 2 |
| 050625 | 04/06/78 | 6.2 | 05/13/85 | 5.7 | - .5 | 7.1 | 2 |
| 050608 | 04/07/78 | 5.4 | 08/09/84 | 5.2 | - .2 | 6.3 | 2 |
| 050404 | 04/25/78 | 5.1 | 04/16/85 | 5.0 | - .1 | 7.0 | 2 |
| 050451 | 04/26/78 | 10.9 | 08/23/84 | 11.0 | + .1 | 6.3 | 2 |
| 050452 | 04/26/78 | 6.8 | 07/19/84 | 6.0 | - .8 | 6.2 | 2 |
| 050835 | 02/05/85 | 5.1 | 09/30/87 | 4.9 | - .2 | 2.7 | 17 |
| 050851 | 03/04/85 | 5.6 | 02/25/86 | 5.4 | - .2 | 1.0 | 10 |
| 050842 | 08/26/85 | 5.3 | 02/25/86 | 5.2 | - .1 | .5 | 10 |

Table 4.--Changes in Aggressive Index values over time--continued.

| Well number | Date of sampling | AI value | Date of sampling | AI value | Change in AI value | Period of record (years) | Number of samples |
|---|---|---|---|---|---|---|---|
| Camden County | | | | | | | |
| 070430 | 03/10/78 | 4.4 | 07/17/84 | 5.0 | +0.6 | 6.4 | 2 |
| 070442 | 03/15/78 | 4.8 | 05/16/85 | 4.9 | + .1 | 7.2 | 2 |
| Ocean County | | | | | | | |
| 290622 | 10/19/60 | 6.0 | 10/26/71 | 5.6 | - .4 | 11.0 | 8 |
| 290521 | 06/22/61 | 9.7 | 09/01/81 | 10.2 | + .5 | 20.2 | 2 |
| 290536 | 06/22/61 | 8.6 | 08/31/61 | 8.8 | + .2 | .2 | 2 |
| 290533 | 08/31/61 | 6.7 | 09/03/81 | 9.5 | + .8 | 20.0 | 3 |
| 290513 | 10/23/61 | 6.7 | 09/20/84 | 7.7 | +1.0 | 22.9 | 4 |
| 290514 | 03/16/62 | 7.5 | 05/24/83 | 6.8 | - .7 | 21.2 | 3 |
| 290566 | 08/15/63 | 4.9 | 08/25/81 | 4.6 | - .3 | 18.0 | 2 |
| 290416 | 04/06/73 | 6.1 | 10/25/84 | 5.7 | - .4 | 11.6 | 3 |
| 290156 | 04/06/73 | 7.8 | 10/26/84 | 5.0 | -2.8 | 11.6 | 2 |
| 290480 | 04/06/73 | 7.1 | 10/25/84 | 4.9 | -2.2 | 11.6 | 3 |
| 290141 | 04/20/82 | 9.2 | 07/10/84 | 8.8 | - .4 | 2.2 | 2 |
| 290731 | 06/24/82 | 5.5 | 09/27/84 | 4.4 | -1.1 | 2.3 | 2 |
| 290058 | 06/29/82 | 7.9 | 11/07/84 | 7.7 | - .2 | 2.4 | 2 |

of these wells have been sampled only for pH, specific conductance, and chloride concentration. Analyses of water from these wells failed the ion-balance test and, thus, were excluded from the data set.

Where human activities have not substantially influenced ground-water chemistry through time, the overall intrinsic character of ground water from the unconfined Kirkwood-Cohansey aquifer system can be described as acidic and soft, with small alkalinity concentrations. Although parts of the aquifer system contain water with a near neutral pH, the calculated corrosion-index values indicate that much of the ground water is highly corrosive and has been so for the period of record.

## Correlations Between Indices

Chemical data were sufficient for the AI and LI to be calculated for all 370 wells. The LSI was calculated for 325 wells and the RCI for 15 wells. Tables 5 to 12 (at end of report) give the calculated values for the LSI, AI, and LI, as well as the chemical constituents and physical characteristics used in the calculations. Table 13 lists the values of the RCI, and compares the values of the LSI, AI, and LI for the same 15 wells.

Table 13.--Comparison of values of the Riddick Corrosion Index with Langelier Saturation Index, Aggressive Index, and Larson Index values for ground water from the Kirkwood-Cohansey aquifer system

[RCI, Riddick Corrosion Index; LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; RCI values are reported to two significant figures]

| Well number | RCI value | LSI value | AI value | LI value |
|---|---|---|---|---|
| 010387 | 770 | -5.1 | 6.7 | 1.0 |
| 010767 | 1,200 | -5.7 | 6.1 | 7.2 |
| 010770 | 7,500 | -6.4 | 5.3 | 4.6 |
| 050455 | 1,600 | -6.0 | 5.8 | 1.9 |
| 110161 | 480 | -5.6 | 6.2 | 1.7 |
| 110237 | 2,100 | -5.1 | 6.7 | 5.8 |
| 290729 | 150 | -4.8 | 7.0 | .9 |
| 290733 | 28 | -5.2 | 6.6 | .2 |
| 290773 | 680 | -5.0 | 6.8 | 9.2 |
| 290789 | 2,300 | -6.5 | 5.3 | 2.0 |
| 290790 | 2,800 | -5.7 | 6.0 | 2.9 |
| 290141 | 8.5 | -2.9 | 8.8 | 1.4 |
| 290791 | 3,100 | -7.0 | 4.8 | 8.6 |
| 290772 | 1,600 | -7.1 | 4.7 | 1.3 |
| 290513 | 140 | -4.1 | 7.7 | 1.3 |

The data (chemical constituents, physical characteristics, and index values) generally were not normally distributed; therefore, rank correlations were used to identify relations between three different indices. The LSI and AI values are highly correlated. A Spearman correlation coefficient of 0.999 was determined for these indices. In general, reasonably good agreement between the LSI and AI ranks would be expected, as a number of the same or similar properties and/or constituents are used to calculate both indices. Rossum and Merrill (1983) show that, for an LSI value of zero, the equivalent AI value is slightly less than 12. Calcium carbonate saturation theoretically is represented by LSI and AI values of zero and 12, respectively. However, because the AI is a less rigorous expression of the LSI, the values calculated are less refined and error is introduced. The regional character of ground water in the Coastal Plain is, however, similarly defined by both indices.

Correlation between ranks of the LI and ranks of the AI generally is negative and less strong than the correlation between ranks of AI and LSI values. The negative correlation arises because LI values increase as the corrosiveness of water increases, whereas AI values (and therefore LSI values) decrease as the corrosiveness increases. Part of the weaker correlation of AI with LI values, as opposed to AI with LSI, lies in the mathematics of the index formulation. The LI is a ratio, whereas the AI and LSI are logarithmic relations. Therefore, values of the LI change differently than do the AI and LSI values, given increases or decreases in input constituent concentrations and parameters. Further, two of the chemical constituents used to calculate

the LI are different from those used to calculate the AI. Therefore, it was expected that the values of the two indices would correlate less well than values for indices calculated using similar constituents.

The data in tables 5 to 12 show that the majority of LI values that are less than 0.5 are associated with water from wells screened at depths greater than 100 ft. The data also show that, for AI values from 10.0 to 11.9 (indicating moderately corrosive water), 13 LI values are less than 0.5 (indicating noncorrosive water), and only 3 LI values are greater than 0.5. However, for AI values less than 10.0 (indicating highly corrosive water), six LI values are less than 0.5 (indicating noncorrosive water). The dissolved-solids concentrations of water samples with AI values of 10.0 to 11.9 generally exceed 100 mg/L and several exceed 250 mg/L; thus, the LI values for these latter samples are valid. The dissolved-solids concentrations tend to be small (less than 250 mg/L) in most samples with AI values less than 10.0, and LI values for these samples need to be viewed with caution. Seven samples with dissolved-solids concentrations greater than 250 mg/L have LI values substantially greater than 0.5, and AI values ranging from 6.4 to 8.9; for these samples, both indices appear to indicate highly corrosive water. The chief value of the LI in this study was as a compact representation of elevated chloride and/or sulfate concentrations relative to alkalinity concentrations, which obviated the necessity of inspecting the data for all three constituents. In this study, the LI is not considered a reliable predictor of corrosiveness, except for waters with dissolved-solids concentrations greater than 250 mg/L. Calculation of the LI for the complete data set showed that high values of the LI (greater than 10) tended to be clustered in samples from urban areas, and this prompted an investigation of the relation between sulfate and chloride concentrations and land use (Barringer and Ulery, 1988).

Although the RCI could not be calculated for most of the wells, the RCI values for a number of the wells indicate that ground water is extremely corrosive in areas where the LSI and the AI indicate highly corrosive water. Rank correlations show that the RCI values do not compare as closely with the LI values as with the LSI and AI values; correlations coefficients are 0.606, -0.768, and -0.782, respectively.

## Correlation of Indices with Depth

Depths to the bottoms of well screens for wells in the data set range from 12 ft to 397 ft from land surface. Although the chemical constituents that affect the corrosiveness of ground water might be expected to vary with depth in the aquifer system, the calculated corrosion-index values indicate that little variation is found in some samples from four of the eight counties in the study area. Where pairs of wells (one shallow, one deep) were sampled in Burlington, Camden, Cumberland, and Ocean Counties, the AI values did not change by more than 1.5 for nearly 60 percent of the pairs of wells. These data suggest that, in many parts of the study area, the ground-water corrosiveness changes little with depth throughout much of the thickness of the aquifer system. Even in an area in Ocean County where the aquifer system is greater than 300 ft thick, water chemistry changes little with depth, and there the corrosiveness of the water is relatively constant with depth. (See table 14, wells 290513 and 290514.)

Table 14.--Aggressive Index values for pairs of wells in the Kirkwood-Cohansey aquifer system

[AI, Aggressive Index]

| Well number | Date of sample | Depth of screen bottom (feet) | AI |
|---|---|---|---|
| Burlington County | | | |
| 050029 | 08/31/61 | 59 | 6.6 |
| 050030 | 03/14/62 | 345 | 9.8 |
| 050409 | 09/09/63 | 17 | 5.8 |
| 050408 | 09/06/63 | 65 | 7.4 |
| 050613 | 04/05/78 | 35 | 5.3 |
| 050612 | 04/05/78 | 272 | 5.8 |
| 050599 | 04/28/78 | 25 | 6.1 |
| 050598 | 04/28/78 | 150 | 6.8 |
| 050418 | 09/03/81 | 46 | 4.5 |
| 050417 | 09/03/81 | 100 | 9.0 |
| 050512 | 09/23/83 | 50 | 4.3 |
| 050511 | 09/23/83 | 250 | 5.4 |
| 050455 | 09/28/83 | 51 | 5.8 |
| 050454 | 09/28/83 | 142 | 8.5 |
| 050452 | 07/19/84 | 21 | 6.0 |
| 050451 | 08/23/84 | 170 | 11.0 |
| 050609 | 08/09/84 | 45 | 5.9 |
| 050608 | 08/09/84 | 160 | 5.2 |
| Camden County | | | |
| 070431 | 03/10/78 | 29 | 5.9 |
| 070430 | 03/10/78 | 120 | 4.4 |

Table 14.--Aggressive Index values for pairs of wells in the Kirkwood-Cohansey aquifer system--Continued

| Well number | Date of sample | Depth of screen bottom (feet) | AI |
|---|---|---|---|
| Cumberland County | | | |
| 110042 | 05/13/86 | 47 | 6.0 |
| 110043 | 05/12/86 | 138 | 6.3 |
| Ocean County | | | |
| 290020 | 10/28/77 | 12 | 9.4 |
| 290017 | 09/21/62 | 397 | 10.8 |
| 290013 | 08/25/81 | 99 | 4.3 |
| 290578 | 08/25/81 | 247 | 5.9 |
| 290513 | 05/24/83 | 21 | 6.8 |
| 290514 | 05/24/83 | 317 | 6.8 |

Local variations in aquifer materials in the Kirkwood Formation part of the system may cause substantial changes in AI (and LSI) values, however. Fossils have been reported in the downdip sediments of the Kirkwood Formation (Owens and Sohl, 1969, p. 252); if the fossils are calcitic, interactions with ground water could locally increase the pH, alkalinity, and calcium concentrations and, thereby, decrease the corrosiveness of that water. Also, for nests of wells in the Mullica River basin, discharge from the underlying Piney Point aquifer may introduce less corrosive water into the Kirkwood Formation part of the aquifer system. Examples of substantial change in estimated corrosiveness with depth are seen in AI values calculated for water from wells 050452 and 050451, and 050029 and 050030 (table 14).

The location of the wells affects the relation between well depth and corrosiveness of water because of the geometry of the aquifer system. For example, in the western part of the study area, where the base of the Cohansey Sand is relatively close to land surface, and some wells tap the Kirkwood Formation part of the aquifer system, AI values tend to be higher for a given well depth than they would be in the central part of the study area. Although the changes are relatively small, AI values in the range of 7 to 9 are seen in the western part of the study area, whereas AI values for wells in the central part of the study area generally are in the range of 4 to 6. Not only does the aquifer system thin to the west, but discharge from the deep part of the aquifer system takes place along parts of the western boundary of the study area. Discharge from the deeper, Kirkwood Formation part of the aquifer system also occurs along the Atlantic Coast, and may be responsible, in part, for decreasing the apparent corrosiveness of water found in some coastal areas.

Because the aquifer system is a volume with irregular geometry, spatial (horizontal) variation in corrosiveness can be considered only in conjunction with (vertical) variation in depth. Similarly, variations in corrosiveness with depth are dependent, in part, upon location within the study area. As an attempt to relate variation in AI values with depth to the spatial variations shown on the maps in plate 1, AI ranks were correlated with depth ranks for each county in the study area. Correlations of two AI input constituent ranks (pH and alkalinity) with depth ranks also were examined, as were LI value ranks with depth ranks, and chloride and sulfate ranks with depth ranks.

The data generally were not distributed normally, and therefore, a Spearman correlation coefficient ($r_s$) was calculated. Whether a particular correlation coefficient indicates a significant correlation depends on the sample size--the smaller the number of samples, the larger the coefficient must be to indicate significance. For a sample size (N) greater than 10, the significance of the rank correlation is tested by calculating Student's t--

$$t = r_s \sqrt{\frac{N - 2}{1 - r_s^2}}$$ (Siegel, 1956).

In Ocean County, the Spearman correlation coefficient ($r_s$) determined for the AI ranks versus depth ranks is 0.028. This coefficient, for a sample set of 168 wells, yields a Student's t-test value of 0.361, which indicates the correlation is not significant at the 0.05 level.

Table 15 lists the rank correlation coefficients for the relations among depth and selected corrosion indices, pH, and selected chemical constituents.

In Salem County, where the Cohansey Sand thins to the southwest, the AI ranks correlate positively with depth ranks at the 0.05 significance level--that is, AI values increase as depth increases. Because high AI values indicate low corrosivity, corrosiveness generally decreases with depth. In Atlantic County, the significant positive correlation of the AI ranks with depth ranks again indicates that the corrosiveness of the water decreases with depth. In Burlington County, a positive correlation of AI ranks with depth ranks is found, but the correlation is not significant at the 0.05 level.

In Gloucester County, the AI ranks are significantly negatively correlated with depth ranks, indicating that the corrosiveness of the water tends to increase (lower AI values) with depth. This increase in corrosiveness is related to the decrease in pH with depth of well screen in Gloucester County. However, in Atlantic, Burlington, and Salem Counties, pH and alkalinity concentrations tend to increase with depth, suggesting the interaction of ground water with reactive minerals within the Kirkwood Formation sediments.

Because some of the AI values were calculated using a value of 1 for alkalinity concentrations reported as less than 1 mg/L, the actual AI values for these samples are lower than the calculated value. (The AI could not be calculated in cases where alkalinity concentrations are known to be zero or negative.) Most of the overestimated AI values are associated with water from wells screened at 100 ft or less; thus the positive correlations of AI with depth would be strengthened if the true, lower value of the AI were known.

Table 15.--Spearman correlation coefficients for relations between depth of bottom of well screen and selected corrosion indices, pH, and selected chemical constituents, by county

[n = number of samples, AI = Aggressive Index, LI = Larson Index, Alk = alkalinity, $SO_4$ = sulfate, Cl = chloride]

| County | Depth/AI | n | Depth/LI | n | Depth/pH | n |
|---|---|---|---|---|---|---|
| Atlantic | * 0.284 | 82 | *-0.263 | 82 | * 0.253 | 82 |
| Burlington | .232 | 54 | *- .473 | 54 | * .370 | 54 |
| Camden | .418 | 12 | *- .710 | 12 | .407 | 12 |
| Cumberland | - .174 | 18 | *- .390 | 18 | .133 | 18 |
| Gloucester | *- .535 | 19 | .138 | 19 | *- .461 | 19 |
| Monmouth | .300 | 5 | - .500 | 5 | .300 | 5 |
| Ocean | .028 | 168 | - .119 | 168 | .098 | 168 |
| Salem | * .753 | 12 | - .105 | 12 | * .515 | 12 |

| County | Depth/Alk | n | Depth/$SO_4$ | n | Depth/Cl | n |
|---|---|---|---|---|---|---|
| Atlantic | * 0.251 | 82 | 0.120 | 82 | *-0.209 | 82 |
| Burlington | * .422 | 54 | *- .269 | 54 | - .238 | 54 |
| Camden | .453 | 12 | *- .576 | 12 | .102 | 12 |
| Cumberland | .191 | 18 | *- .508 | 18 | *- .526 | 18 |
| Gloucester | - .286 | 19 | .065 | 19 | - .127 | 19 |
| Monmouth | .300 | 5 | - .300 | 5 | - .103 | 5 |
| Ocean | .056 | 168 | - .030 | 168 | *- .196 | 168 |
| Salem | * .599 | 12 | .322 | 12 | .011 | 12 |

* Correlation is significant at the 0.05 level.

Further, in most of the counties, the number of overestimated AI values is small. In Atlantic County, however, 23 percent of the AI values are overestimates. Most of the overestimated values (13 of 19) are associated with shallow (less than 100 feet) wells; therefore, the significant positive correlation (higher AI values with increasing depth) most likely would change little if the true AI values were known. For Camden County, where 50 percent (6 of 12) of the AI values are overestimates, and four of these six overestimated values are associated with shallow wells, the correlation shown in table 15 might be significant if the true AI values were known. In Cumberland County, the slight negative correlation of AI with depth (decreasing AI values with depth) is not significant. However, 3 of 18, or about 17 percent, of the AI values are overestimates. Two of the three overestimated AI values are associated with water from shallow wells. If the true AI values were known, the slight negative correlation shown in table 15 could be replaced by a slight positive correlation.

Overestimating index values by substituting alkalinity concentrations of 1 mg/L for concentrations less than 1 mg/L also affects the LI values. Because the LI is a ratio, the effect of a smaller denominator (less than 1) would be to increase the LI value. Therefore, the correlations of ranked LI with ranked depth shown in table 15 are tentative. However, the rank correlation coefficients of LI with depth indicate relations that are similar to those shown for sulfate with depth, and, in some cases, are also comparable to the relations of chloride with depth.

In four of the eight Coastal Plain counties (Atlantic, Burlington, Camden, and Cumberland Counties), the LI values estimate that corrosiveness of ground water decreases significantly with depth, indicated by a significant negative correlation of LI values with depth. A significant decrease in corrosiveness of water at depth also is indicated by AI values for Atlantic County. Chloride concentrations tend to decrease significantly with depth in Atlantic, Cumberland, and Ocean Counties, whereas sulfate concentrations decrease significantly with depth in Burlington, Camden, and Cumberland Counties. The decrease in chloride concentrations with depth indicates possible surficial sources for chloride. Sulfate sources also may be surficial, but, unlike chloride, sulfate can be involved in a variety of reactions in both the unsaturated and saturated zones. Bacteria and plants can remove sulfate from the meteoric waters that recharge the aquifer system. Adsorption of sulfate to minerals in acidic soils and aquifer materials removes sulfate from meteoric water and from ground water. The reduction of sulfate to sulfide in anaerobic waters at depth is another possible mechanism for the removal of sulfate. Therefore, the interpretation of the decreasing trend for sulfate with depth is less certain than the interpretation for chloride.

Overall, these statistical data indicate some depth dependence for the corrosion-index values, constituent concentrations, and pH. Although many of the correlations shown in table 15 are not significant at the 0.05 level, the number of data points for some counties are limited, and apparently insignificant trends or relations reported here could become significant if the data set were larger. If the reporting level for alkalinity concentrations were reduced, the accuracy of some of the calculated AI values would improve, and could change the significance of the reported correlations.

However, given the available data, the most consistently observed trend is a decrease in acidity and corrosiveness of water with depth in some parts of the aquifer system (primarily Atlantic, Burlington, and Salem Counties).

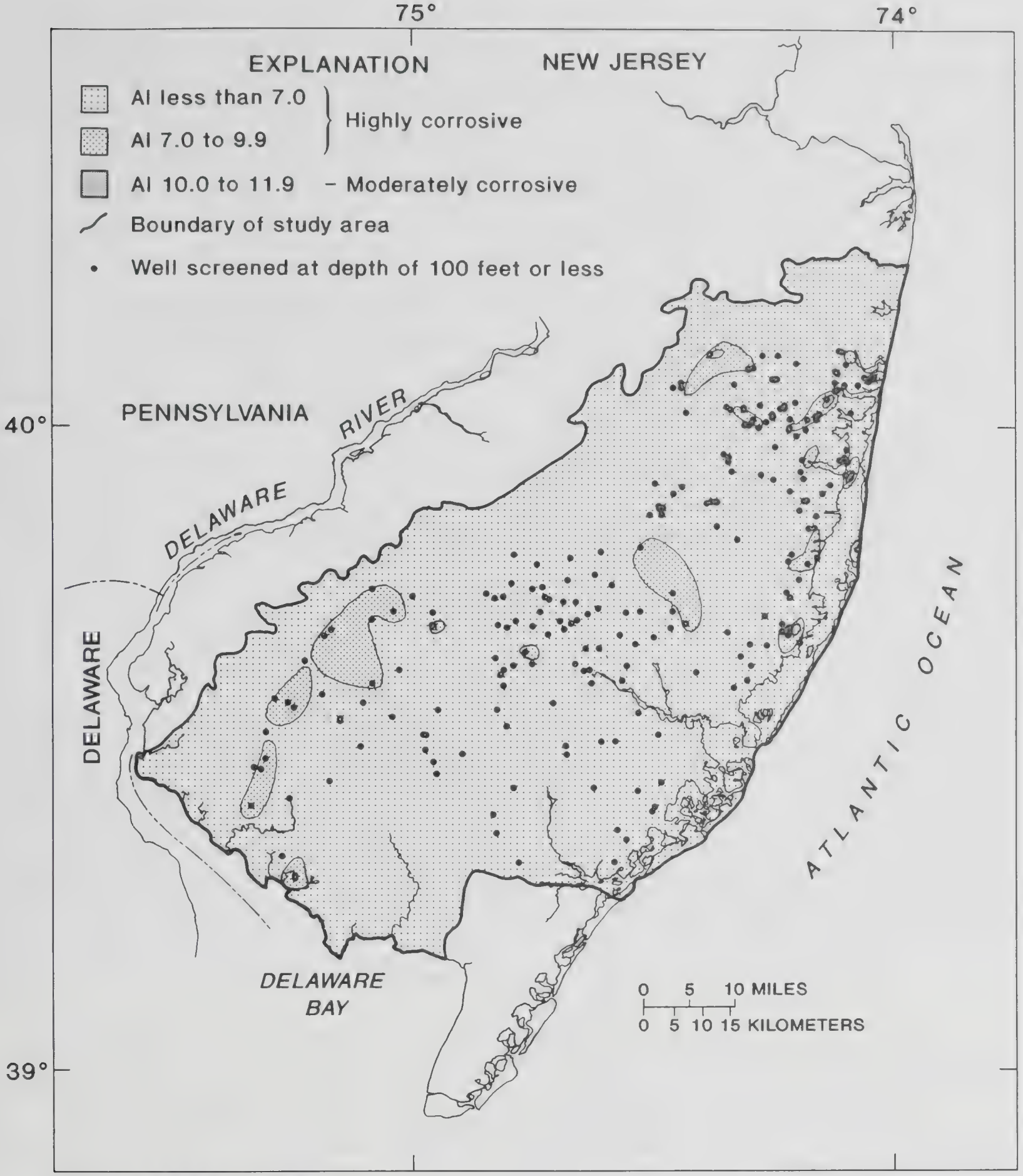
## Spatial Relations

Plate 1 shows many more AI values of less than 10.0, indicating highly corrosive water, than values greater than 10.0, indicating moderately corrosive water. The median of AI values calculated for 370 wells is 6.0. No AI values of 12.0 or greater were calculated for the 370 wells. The AI values indicate that ground water is estimated to be corrosive in the unconfined Kirkwood-Cohansey aquifer system. Highly corrosive water is dominant within the shallow (less than 100 ft deep) part of the aquifer system, as summarized in figure 8. Based on AI values, some coastal ground water along the northern part of the study area appears to be moderately corrosive. Moderately corrosive ground water also is present in the northern part of the study area. In the study area, in shallow and deep wells, AI values ranged from 3.9 (for water from an 89-foot-deep inland well in Ocean County) to 11.9 (for water from an 180-foot-deep well in Atlantic County). Moderately corrosive water (AI between 10.0 and 11.9) was found in wells deeper than 100 feet in areas near Delaware Bay.

Ground water in the inland part of the outer Coastal Plain generally is estimated by AI values of 7.0 or less to be highly corrosive, but water with AI values that approach 10.0 (which begins the moderately corrosive category) can be found in and near the outcrop area of the Kirkwood Formation. Several wells from the vicinity of the upland dwarf-pine forest of the Pine Plains (see fig. 5) yielded water with higher AI values (indicating slightly less corrosive water) than that found in other forested parts of the outer Coastal Plain. Although the AI values for the Pine Plains area indicate that the ground water is highly corrosive, the values range from 7.8 to 9.0, well above the median AI value of 6.0 for the entire study area.

Because the LSI also represents the saturation state of water with respect to calcium carbonate, the results obtained for the LSI values indicate virtually the same patterns of estimated corrosiveness as do the AI values. The LI values also show somewhat similar areal patterns as do the LSI and AI values--that is, potentially noncorrosive ground water in a few coastal and northern areas, and potentially corrosive ground water inland.

The LI may not be an appropriate index to estimate the corrosiveness of dilute waters from the Kirkwood-Cohansey aquifer system. However, the results obtained from LI values correspond fairly well to the values obtained for the other indices in that most of the ground water in the Kirkwood-Cohansey aquifer system is estimated by the LI to be potentially corrosive. Ground water in the inland area of the Coastal Plain generally is shown to be corrosive by LI values because alkalinity concentrations in water from the inland area typically are small. Although chloride and sulfate concentrations generally are less than 5 mg/L throughout many of the inland parts of the Coastal Plain, sulfate concentrations tend to be slightly elevated (8 to 18 mg/L) in forested wetlands in and near Lebanon State Forest and Wharton State Forest (fig. 1). Chloride and sulfate concentrations are moderately elevated (as high as 40 and 70 mg/L, respectively) in water from wells in agricultural areas, as well as urban areas such as Vineland and Lakewood. Elevated




Base from State of New Jersey orthophoto quads, 1:24,000

Figure 8.--Zones indicating corrosiveness of shallow ground water as estimated by the Aggressive Index (AI). (Data are from wells screened at a depth of 100 ft or less in order to minimize the effect of change in AI values with depth.)

chloride concentrations (in the range from approximately 6 to 40 mg/L) also are associated with major roadways such as the Atlantic City Expressway and U.S. Route 206. LI values for coastal urban areas indicate that ground water is potentially corrosive; these are areas where AI values may only indicate moderately corrosive ground water. Figure 9 shows the distribution of selected LI ranges for shallow ground water. The data used are for wells screened at depths of 100 ft or less in order to minimize the effect of changes in LI values with depth.

## Factors That Affect Ground-Water Chemistry

The chemistry of ground water in unconfined aquifers can be affected by a number of natural and anthropogenic factors. Precipitation chemistry, land cover (including vegetation), land use, topography, soils, geology (aquifer materials), hydraulic conductivity, and areas of recharge and discharge all can influence ground-water chemistry. Anthropogenic factors primarily relate to land use, and include various farming practices, salting of roads, water withdrawals, and a variety of industrial and waste-disposal practices. The effects of anthropogenically produced "acid precipitation" on ground-water chemistry in the Coastal Plain of New Jersey are not clearly understood.

### Precipitation

The chemistry of precipitation potentially can have an influence on the chemistry of shallow ground water in unconfined aquifers, although interactions with vegetation and soils can change the chemistry of meteoric water as it moves toward the water table. Precipitation in the northeastern United States has been strongly acidic for decades; data from the mid-1950's and 1980's indicate precipitation pH for the New Jersey area generally has been less than 4.6 (Turk, 1983; Lord and others, 1987). Precipitation has small concentrations of alkalinity; negative alkalinities are measured by Gran titration in samples collected in Burlington County (Lord and others, 1990). Sulfate is the dominant anion in acidic precipitation over the northeastern United States (Galloway and others, 1984).

### Soils and Vegetation

The sandy soils that have developed on the Kirkwood and Cohansey Formations generally are strongly to extremely acid (pH range of 5.5 to less than 4.5, Hole and Smith, 1980, p. 53), except where cropland has been limed for long periods of time (Markley, 1979). Some coastal-area soils are reported to be slightly to strongly acid (pH 5.5 to 6.5). Tidal-marsh soils generally are near neutral when wet, but become extremely acid when dry (Johnson, 1978, p. 27).

Much of the study area is forested. The pH of precipitation passing through the predominantly coniferous canopy tends to become more acidic (Turner, 1983, p. 75). Organic acids are generated by decomposition of the litter layer, and sandy soils contain relatively small amounts of clay to react with acidic meteoric water. Further, pine vegetation, because of a low content of base cations (calcium, magnesium, sodium, and potassium) in plant tissue, tends to promote the development of soil acidity (Brady, 1974, p. 306). The upper horizons (O and A) of Pine Barrens soils typically are more acidic than the lower horizons (B and C). The acidity of meteoric water

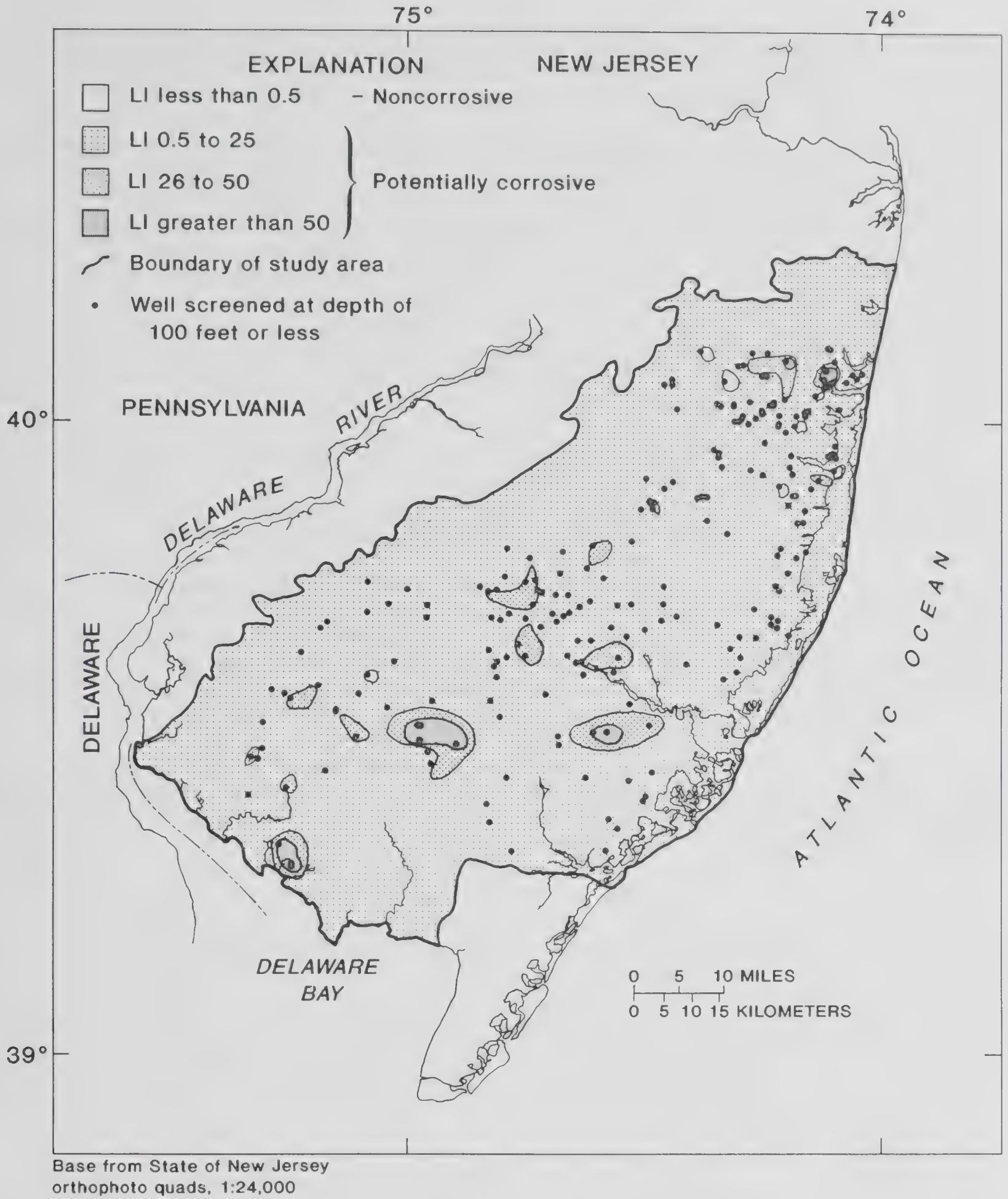



Figure 9.--Distribution of selected Larson Index (LI) value ranges. (Data are from wells screened at a depth of 100 ft or less in order to minimize the effect of changes in LI values with depth.)

moving through the soil horizons can decrease slightly with depth in the soil profile and alkalinity can increase slightly as a result of weathering reactions and bacterial activity.

In the study area, water beneath upland-forest recharge areas typically is highly acidic, with small concentrations of alkalinity. Highly acidic ground water (pH less than 5.0) with slightly elevated concentrations of sulfate tends to underlie and discharge to forested wetlands and bogs. In the upland forest of dwarf pitch pine known as the Pine Plains, water from two shallow wells (050628 and 050029; 12 and 59 ft deep) has slightly higher pH and higher alkalinity concentrations than water from wells in nearby forested areas. Wildfires are reported to have occurred more frequently in the Pine Plains than elsewhere in the Pine Barrens (Lutz, 1934). This fire history is believed to have played a role in the development of a forest containing sparsely distributed dwarf pines and heath shrubs (Good and others, 1979).

Wang (1984), in a study of fire and nutrient dynamics in a pine-oak ecosystem, found that the pH of leachate from lysimeters containing a Pine Barrens soil with ashed vegetation was substantially higher (8.4 to 7.3) for the period of measurement (seven months) than the pH of leachate (4.6 to 3.7) from soil without ash. Because ground-water quality in recharge areas can be affected by surficial and unsaturated-zone processes, increases in soil-water pH and alkalinity caused by frequent burning of vegetation could, in turn, cause local increases of pH and alkalinity in shallow ground water. This is a plausible explanation for the slightly elevated pH and alkalinity concentrations in water from the Pine Plains, which appear anomalous in the context of the regional water quality.

In most recharge areas in the Outer Coastal Plain, however, the water that moves through the unsaturated zone and enters the shallow aquifer system commonly bears chemical similarities to acidic precipitation, although the ground water is less dilute than precipitation.

## Topography and Land Use

In the study area, a relation between topography and ground-water chemistry is not apparent. Low-lying coastal areas of southern New Jersey typically are areas of ground-water discharge. Ground water moving along regional flow paths to the coast has a long residence time in deep aquifer materials which can promote the evolution towards a less acidic water than that found in the shallow part of the system. In some cases, the chemistry of coastal ground water also appears to reflect the proximity of the freshwater/saltwater interface. Thus, ground water in parts of the coastal lowlands tends to have higher pH, larger alkalinity and dissolved-solids concentrations, and is harder than ground water from lowlands in the central part of the Outer Coastal Plain. Lowland discharge areas inland generally are associated with soft, acidic ground water, although water from wells located near the outcrop area of Kirkwood Formation sediments commonly is slightly harder and less acidic. Ground water from upland recharge areas in the interior also tends to be soft and acidic, but a few samples from the Pine Plains, as discussed in the section on "Soils and Vegetation" indicate slightly less acidic water in the Plains area.

As indicated in the section "Spatial Relations," urban land use throughout the study area appears to influence concentrations of sulfate and chloride in shallow ground water (less than 100 ft deep). Moderately elevated sulfate concentrations (20 to 50 mg/L) are present in ground water beneath urban areas such as Lakewood and Vineland. Slightly to moderately elevated chloride concentrations (8 to 42 mg/L) in shallow ground water from inland areas tend to be associated with major roadways and with urban areas (Barringer and Ulery, 1988). Water withdrawals in urbanized coastal areas in Atlantic and Ocean Counties have tended to increase the salinity of ground water locally (Schaefer, 1983).

The increase in ground-water corrosiveness with depth in Gloucester County, as estimated by decreasing AI values with depth, is, in part, a reflection of agricultural activities. Calcium-hardness values are elevated in water from five relatively shallow wells (less than 125 ft deep) in agricultural areas (wells 150041, 150048, 150726, 150729, and 150730 (table 9)). In Gloucester County, farmers typically lime fields with dolomite ($CaMg(CO_3)_2$), and calcium and magnesium generally are elevated in ground water from Gloucester County agricultural areas (J. Kozinski, U.S. Geological Survey, oral commun., 1989).

Despite comparatively larger calcium hardness concentrations observed in water from several Gloucester County wells, alkalinity and pH are fairly low (see table 9) in water from these wells. The low pH and alkalinity may be maintained, in part, by bacterially mediated processes, such as nitrification. The input of nitrogen to the system is apparent in nitrate concentrations commonly larger than 3 mg/L in ground water beneath agricultural areas in Gloucester County (J. Kozinski, U.S. Geological Survey, oral commun., 1989). It also is likely that organic acids buffer the system against changes in pH. An effect of the elevated calcium hardness concentrations, even with pH values less than 5.0 and alkalinity concentrations less than 5 mg/L, is to yield AI values that indicate slightly less corrosive water than that found beneath undeveloped areas. In addition to lowering the estimated corrosiveness of water, elevated concentrations of calcium hardness can affect interactions between plumbing materials and ground water. Specifically, lead solubility is reduced as the calcium concentration of water increases (Moore, 1973). However, chloride and sulfate concentrations also are elevated at some wells in agricultural areas; sulfur can be present in various agricultural chemicals, and potassium chloride also is applied as a source of potassium for plants. It is not known if elevated sulfate and chloride concentrations offset the apparently beneficial effect of elevated calcium concentrations.

Much of Cumberland County also is agricultural land; calcium-hardness concentrations are elevated at a number of relatively shallow (less than 130 ft) wells (wells 110073, 110083, 110093, 110100, 110287, 110289, 110360, 110367, and 110369, (table 8)). These wells are in or adjacent to agricultural areas where liming with dolomite is practiced. Like the wells in Gloucester County, wells in Cumberland County tend to yield water with elevated concentrations of chloride and sulfate; however, no significant effect of depth on ground-water corrosiveness is apparent in the rank correlation coefficient for AI versus depth calculated for wells in Cumberland County. This lack of significant correlation with depth occurs because AI values associated with two deep wells (110097 and 110119) exceed 10.0,

indicating that the water is only moderately corrosive. The AI values for these two wells statistically offset any effect on AI values by surficial inputs, such as those that result from farming practices.

In Salem County, where agricultural land also is fairly extensive, the reverse of the Gloucester County pattern is seen. Calcium hardness, chloride, and sulfate concentrations are elevated in water from wells in agricultural areas. However, AI values tend to increase with depth, indicating a reduction in water corrosiveness with depth. This is largely because of the increase in pH and alkalinity concentration with depth in Salem County. Figure 10 compares plots of AI versus depth of well screen for Gloucester, Cumberland, and Salem Counties; raw data, rather than ranked data, are plotted.

## Geology

Quartz sand is the dominant geologic material of the upper part (Cohansey Sand) of the Kirkwood-Cohansey aquifer system. The sand is highly permeable (Rhodehamel, 1979b, p. 153). With the exception of scattered clay lenses, clays and other reactive minerals are sparse. As the water moves along flow paths within the aquifer system, the mineralogy of the upper part of the aquifer system maintains the acidity of the water because calcium carbonate buffers are absent and few weatherable silicate minerals are present that are capable of neutralizing acidic waters.

Fine sands, silts, and clayey silts are more abundant in the lower part of the aquifer system (Kirkwood Formation) than in the upper part (Cohansey Sand) of the system. Clays can exert a neutralizing effect on acidic waters, unlike the sands in the upper part of the aquifer system. Where the Cohansey Sand is thin, and wells yield water from the lower (Kirkwood Formation) part of the aquifer system, ground water tends to be less acidic than in other inland areas of the Outer Coastal Plain. Because reactive silicate minerals are more abundant in sediments of the Kirkwood Formation than in those of the Cohansey Sand and shell material can be present, ground water in the lower (Kirkwood) part of the system can evolve chemically towards less acidic, more bicarbonate-rich water. Locally, a sharp decrease in the corrosiveness of water with depth can be seen (see Burlington County wells 050452 and 050451 (table 14)), which can result from buffering by calcium carbonate shell material, clays such as illite, or glauconite at depth within the Kirkwood Formation part of the aquifer system. Overall, acidity (and corrosiveness) of water in the deeper part of the aquifer system can decrease through interactions with geologic materials. In some areas, however, deep wells tap water that is as corrosive as water in shallow parts of the system (see Ocean County wells 290513 and 290514 (table 14)).

## Hydrogeology

Hydraulic conductivity within the Kirkwood-Cohansey aquifer system is variable; the highest values are associated with the sandier parts of the aquifer (Rhodehamel, 1973). A range of hydraulic conductivity values have been calculated (90 to 250 ft per day; Rhodehamel, 1979b, p. 154), with common values reported as 130 to 150 ft per day (Rhodehamel, 1973, p. 30). Where aquifer materials are fine-grained and contain abundant clay (the Kirkwood Formation), hydraulic conductivity decreases. The decrease in hydraulic conductivity decreases ground-water flow velocity. Reduction in flow velocity

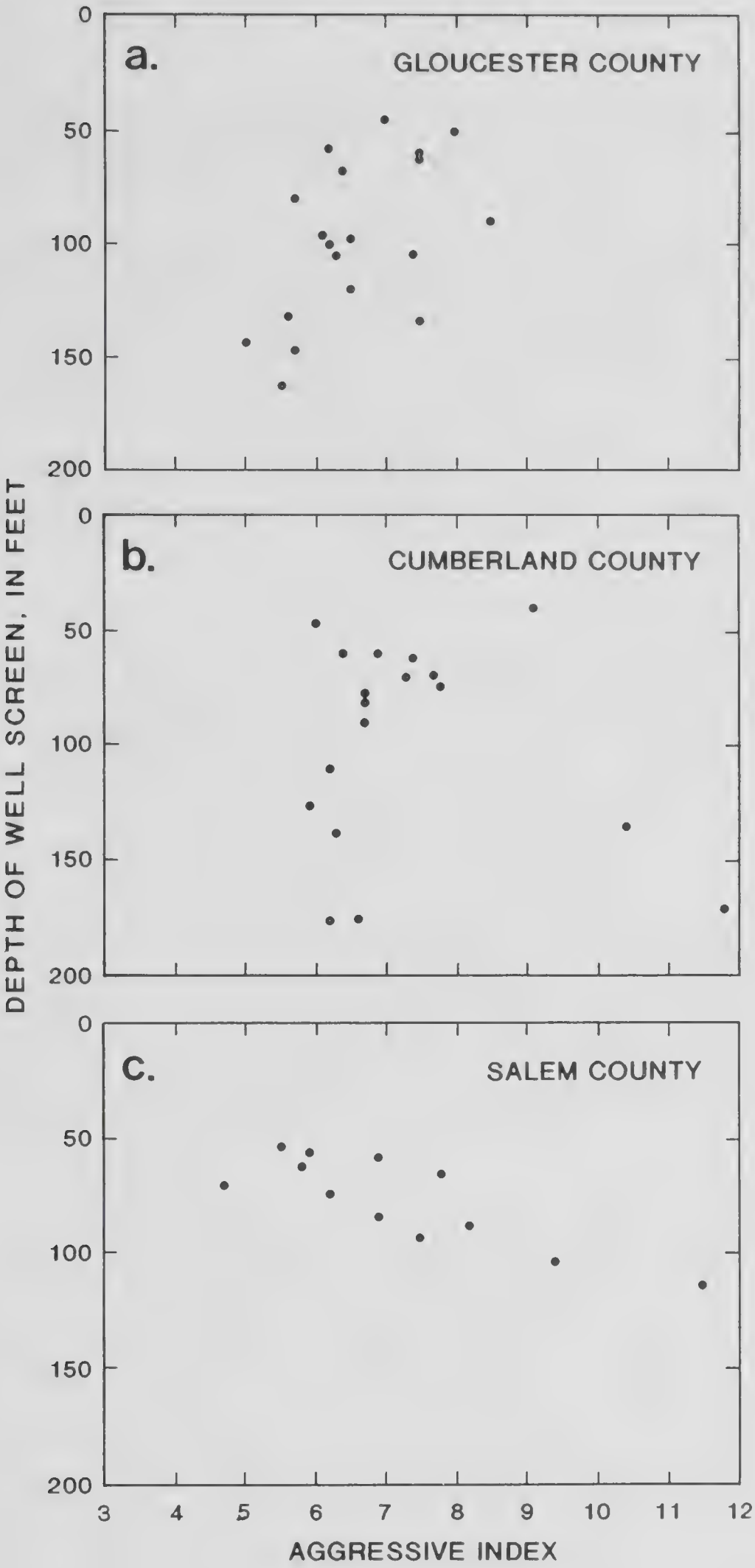



Figure 10.--Change in Aggressive Index value with depth for (a) wells in Gloucester County; (b) wells in Cumberland County; and (c) wells in Salem County.

in fine-grained aquifer materials increases the period (residence time) that the water is in contact with reactive materials; this tends to increase the alkalinity and pH of the ground water through weathering reactions.

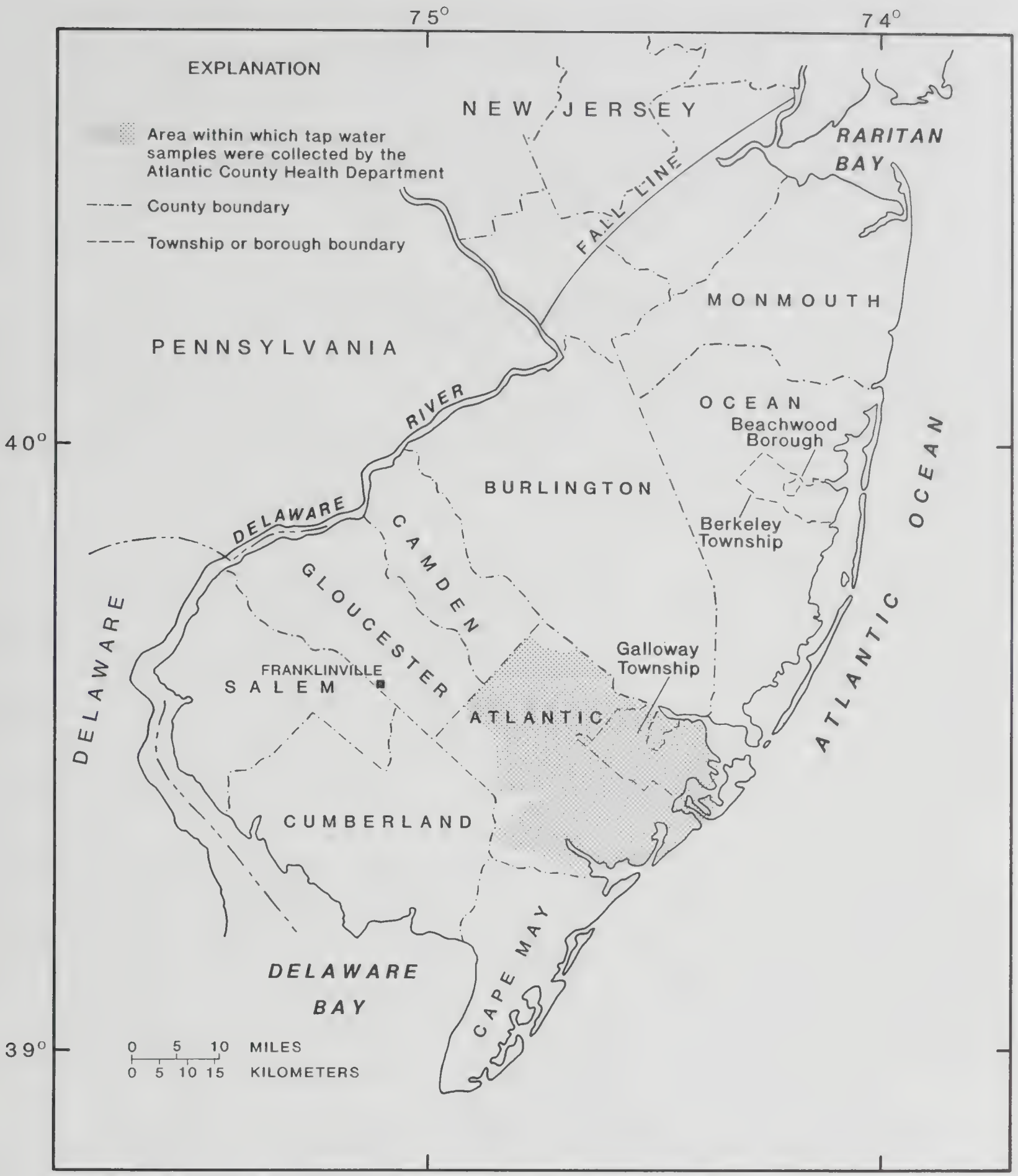
In much of the central part of the study area, shallow ground-water chemistry appears to remain relatively constant along short flow paths because ground water recharges and discharges locally. Even in areas where recharge extends to the deep part of the aquifer system, ground-water chemistry commonly does not change greatly with increasing depth. A substantial change in chemistry in a section through the aquifer system is seen, however, in water from a nest of wells in Burlington County (wells 050452 and 050451 (tables 6 and 14)). These wells are located in the discharge area within the Mullica River basin, where chemically different water from underlying glauconitic formations (the Piney Point or Manasquan Formations) probably moves up into the Kirkwood-Cohansey aquifer system (Rhodehamel, 1973, p. 35).

## SUBSTANTIATION OF GROUND-WATER CORROSIVENESS

If a corrosion index is used to estimate the corrosiveness of a given water, it is prudent to verify the predictive accuracy of the index values by field or laboratory studies. Field studies of trace-metal leaching by tap water were available to substantiate the corrosiveness of the waters evaluated in this study (Kish and others, 1987; Deborah Maher, Atlantic County Health Department, written commun., 1988; table 16, this study). Locations of areas from which tap-water samples were collected are shown in figure 11.

In 1984, tap water was sampled in three areas where moderately corrosive to highly corrosive ground water is predicted by the calculated indices. The areas sampled were Beachwood Borough and Berkeley Township in Ocean County, and Galloway Township in Atlantic County. Standing tap water (water that had stood in the plumbing overnight) from recently built houses in Beachwood Borough and Berkeley Township was collected and analyzed. Standing tap water and running tap water from new houses in Galloway Township were sampled (Kish and others, 1987). All houses had copper plumbing joined with lead/tin solder.

In Beachwood Borough, concentrations of lead in standing tap water from seven houses ranged from 6 to 89 µg/L. Concentrations of copper ranged from 13 to 650 µg/L. Water from 11 houses less than 1 year old in Berkeley Township was sampled; each of the 11 houses had an in-line water-treatment system. In the samples from the Berkeley Township houses, lead concentrations ranged from 2 to 400 µg/L, with a median value of 101 µg/L. Copper concentrations as large as 1,450 µg/L were found. Concentrations of both metals in standing tap water from several new houses in Galloway Township were even larger; maximum concentrations were 800 µg/L for lead and 12,300 µg/l for copper. However, lead and copper concentrations decreased to less than the New Jersey drinking-water criteria of 50 µg/L for lead and 1,000 µg/L for copper (New Jersey Department of Environmental Protection, 1985) in the running-water samples, indicating that ambient lead and copper concentrations in ground water in these areas are small. The leaching action of corrosive ground water on lead/tin solder and copper pipe probably is the cause of the elevated lead and copper levels (Kish and others, 1987).




Base from U.S. Geological Survey
1:250,000 quadrangles

Figure 11.--Locations of areas from which tap-water samples were collected.

A subsequent study of lead in tap water by the Atlantic County Health Department included houses in Galloway, Egg Harbor, Mullica, and Hamilton Townships. The ground water in this area is estimated to be highly corrosive by the AI values calculated for wells in Atlantic County. The results from the Health Department study indicate that lead concentrations in standing tap water from recently constructed houses commonly exceed the current New Jersey drinking-water criterion of 50 μg/L. However, lead concentrations decreased in the tap-water samples after several minutes of flushing (Deborah Maher, Atlantic County Health Department, written commun., 1987), a result that is similar to the results of Kish and others' (1987) previous study in Galloway Township.

In 1987, tap-water samples were collected from a group of ten 2- to 4-year-old houses in Franklinville, Gloucester County. The houses were supplied with water from domestic wells, and all had copper plumbing joined with lead/tin solder. Four of the houses had in-line water-treatment systems. Samples of standing and running tap water were collected and analyzed for trace elements and major cations. The running-tap-water samples (collected after 15 minutes of flushing the system) were analyzed for trace elements, major cations, alkalinity, chloride, and sulfate. This latter group of samples was assumed to represent aquifer water tapped by the homeowners' wells.

The results of the analyses indicated that copper concentrations larger than 2,000 μg/L could be reached after 5 to 8 hours of leaching. Lead concentrations in standing tap water from these houses did not exceed 40 μg/L, however, and thus did not exceed the New Jersey drinking-water criterion for lead (50 μg/L). Lead and most copper concentrations in Franklinville tap water were below the detection limit of 10 μg/L after 15 minutes of flushing, indicating that the concentrations of these metals in the ground water is small. Table 16 summarizes data for 10 houses in the Franklinville area. AI values calculated for well water (from the 15-minute flush data) from each house are included.

The ten houses in Franklinville, Gloucester County, were built by the same firm, and were relatively similar in construction; therefore, they probably had relatively similar plumbing systems. The length of copper pipe and number of soldered joints plays an important role in the concentrations of copper and lead in standing tap water, as does the length of time the water stands in the pipes. Table 16 shows no clear pattern of increased lead and copper concentrations with time, although, for those houses without water-treatment systems, the highest copper and lead concentrations were found in water that stood for the longest period of time.

The relatively small concentrations of lead and copper in the Franklinville samples, compared with the concentrations reported by Kish and others (1987) for houses in Galloway Township, Atlantic County, are related, in part, to the age of the houses. The Franklinville houses were slightly (one to three years) older than the houses in Galloway Township, Atlantic County, and are likely to have had more substantial pipe-scale deposits to shield the plumbing from corrosive ground water.

Table 16.--Summary of lead (Pb) and copper (Cu) concentrations in standing tap water and in tap water after 15 minutes of flushing the system, from 10 houses in Franklinville, New Jersey, February 1987

[Time = length of time water stood in the plumbing; AI, Aggressive Index value; Pb, lead concentration; Cu, copper concentration; μg/L, micrograms per liter; <, less than]

| Time | Standing tap water | | Fifteen-minute flush | | AI |
|---|---|---|---|---|---|
| | Pb | Cu | Pb | Cu | |
| (hours) | (μg/L) | (μg/L) | (μg/L) | (μg/L) | |
| 8.5 | 40 | 3,400 | <10 | 50 | 6.3 |
| 7.4 | 20 | 470 | <10 | <10 | 5.5 |
| 5.5 | <10 | 50 | <10 | <10 | 7.2 |
| 5.7 | <10 | 2,100 | <10 | 130 | 5.4 |
| 7.2 | <10 | 20 | <10 | <10 | 7.9 |
| 6.3 | 40 | 320 | <10 | <10 | 8.3 |
| 9.3 | <10 | 140 | <10 | 110 | 11.8* |
| 7.8 | <10 | <10 | <10 | <10 | 10.0* |
| 8.3 | <10 | 20 | <10 | <10 | 9.3* |
| 7.2 | <10 | 70 | <10 | <10 | 8.9* |

* House for which this Aggressive Index value was calculated had an operating in-line water-treatment system. Water-treatment systems included 3 pH conditioners and 1 water softener.

Water temperature also can have played a role in the metal concentrations; tap water from the Franklinville houses were sampled in February, whereas tap water from the Galloway Township houses was sampled in May (G.R. Kish, U.S. Geological Survey, written commun., 1984). Because metals typically are more soluble in warm water than in cold, lead and copper concentrations in standing tap water sampled in winter are likely to be smaller than concentrations in water sampled in warm months. This effect has been noted in tap-water samples collected in winter and summer months in Pennsylvania (W.E. Sharpe and D.R. DeWalle, Penn State University, written commun., 1989).

Despite age of plumbing and temperature factors, the estimated corrosiveness of water from the Kirkwood-Cohansey aquifer system generally is borne out by the metal concentration data. AI values calculated for water from the Galloway Township area tended to be slightly lower (mostly between 5.2 and 6.5 (pl. 1)) than AI values calculated for water in the Franklinville area (between 5.4 and 8.3 (table 16)). In particular, the AI values for water that had passed through a treatment system were higher than those calculated for water from houses with no treatment system (table 16). Figure 12 shows that the calculated AI values predict adequately the corrosiveness of the Franklinville tap water, as evidenced by the amount of copper leached into the standing tap water.

## SUMMARY AND CONCLUSIONS

Corrosion indices were calculated for ground water from the Kirkwood-Cohansey aquifer system in the New Jersey Coastal Plain. The Agressive Index (AI) values of 10.0 to 11.9 estimate that the harder, less acidic ground water found in some coastal areas generally is less corrosive than the soft, acidic waters found inland, where AI values range from 3.9 to 9.9. Values for several corrosion indices indicate that ground water underlying most of the outer Coastal Plain is highly corrosive. The median of the AI values calculated for 370 wells is 6.0, indicating that the water is highly corrosive. Values calculated for the Langelier Saturation Index (LSI) indicate a spatial pattern similar to that shown by AI values. Spatial patterns of Larson Index (LI) values show some similarity to the patterns of the AI and LSI. Although the reliability of the LI for use in dilute waters is not known, calculated LI values suggest that water underlying some agricultural and urban areas can be more corrosive than indicated by the calculated AI values, because the AI does not account for concentrations of sulfate and chloride that commonly are elevated in water beneath these areas.

The quartz sands in the Kirkwood-Cohansey aquifer system are chemically relatively inert compared to many other minerals, and the chemistry of ground water generally changes little along short flow paths. Changes in ground-water chemistry with depth tend to be relatively small throughout much of the aquifer system. In general, water from wells that tap the Kirkwood Formation part of the aquifer system tends to be less acidic, with higher alkalinity and calcium hardness than water from the upper, Cohansey Sand part of the aquifer system. Overall, water from the wells sampled is estimated to be highly to moderately corrosive; highly corrosive water appears to be dominant.

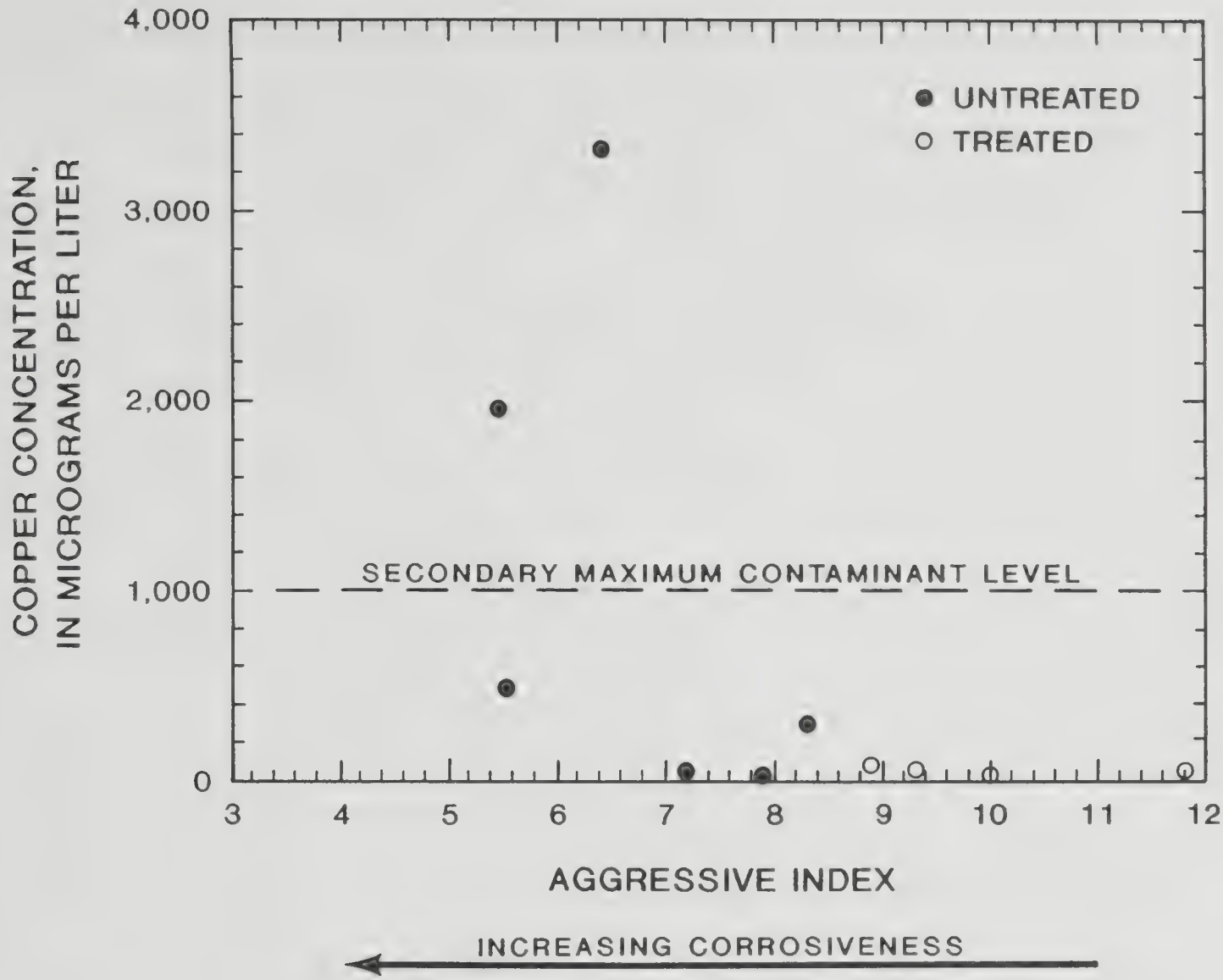



Figure 12.--Aggressive Index values versus concentrations of copper leached from plumbing in 10 houses in Franklinville, Gloucester County, February 23, 1988. (The dashed line represents New Jersey Secondary Drinking-Water Criterion for copper (New Jersey Department of Environmental Protection, 1985), which is equal to the Secondary Maximum Contaminant Level established by the U.S. Environmental Protection Agency (1977).)

The estimated corrosiveness of ground water in several areas has been substantiated by studies of trace-element concentrations in tap water. Elevated concentrations of lead and copper were found in standing tap water from recently constructed houses in areas where the corrosion indices indicate that the ground water is highly corrosive. Although a ban on the use of lead/tin solder for potable water systems has been in effect in New Jersey since early 1987, the potential remains for leaching trace elements from plumbing already in place. The potential also exists for the dissolution of asbestos-cement pipe and for corrosion of storage tanks and other metallic structures in contact with water from the Kirkwood-Cohansey aquifer system.

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Table 5.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Atlantic County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft below LSD) | pH (standard units) | Alkalinity (mg/L as $CaCO_3$) | Calcium hardness (mg/L as $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| [illegible] | 392554 | 743027 | 05/15/64 | 205[a] | 4.9 | 2 | 3 | -- |
| [illegible] | 393024 | 745809 | 07/06/87 | 97[a] | 4.4 | <1[b] | 115 | 14.5 |
| [illegible] | 393240 | 745619 | 10/02/85 | 172[a] | 4.8 | 2 | 15 | 13.5 |
| [illegible] | 392732 | 745342 | 10/16/85 | 194[a] | 4.6 | 2 | 5 | 13.0 |
| [illegible] | 392914 | 745609 | 10/18/85 | 120[a] | 4.6 | <1 | 33 | 14.5 |
| [illegible] | 393004 | 745335 | 11/01/85 | 47 | 4.4 | <1 | 19 | 16.5 |
| [illegible] | 392241 | 743544 | 10/10/84 | 135 | 4.9 | 3[b] | 7 | 14.0 |
| [illegible] | 392244 | 743455 | 10/12/84 | 127 | 4.7 | 2[b] | 7 | 13.5 |
| [illegible] | 392255 | 743503 | 10/10/84 | 70 | 5.2 | 4[b] | 2 | 14.0 |
| [illegible] | 392254 | 743434 | 10/12/84 | 123 | 5.0 | 3[b] | 2 | 14.5 |
| [illegible] | 392515 | 743824 | 10/03/85 | 157 | 5.2 | 3 | 1 | 14.5 |
| [illegible] | 393414 | 744927 | 09/06/85 | 53 | 5.4 | 4 | 1 | 13.0 |
| [illegible] | 393711 | 745124 | 07/26/85 | 104 | 5.0 | 3 | 5 | 15.5 |
| [illegible] | 392650 | 742752 | 10/24/85 | 201 | 4.8 | 2 | 2 | 13.5 |
| [illegible] | 392723 | 742945 | 10/24/85 | 64 | 5.1 | 3 | <1 | 12.5 |
| [illegible] | 392813 | 743151 | 09/27/84 | 110 | 5.0 | 4 | 1 | 13.0 |
| [illegible] | 392919 | 743605 | 09/17/85 | 173 | 4.7 | 2 | 2 | 15.0 |
| [illegible] | 392938 | 743127 | 10/31/85 | 150 | 4.7 | 2 | 1 | 12.5 |
| [illegible] | 393025 | 743816 | 09/04/85 | 136[a] | 5.2 | 3 | 12 | 14.0 |
| [illegible] | 393114 | 743654 | 09/17/85 | 75[a] | 4.5 | <1 | 35 | 14.0 |
| [illegible] | 393114 | 743654 | 07/28/87 | 77[a] | 4.5 | <1[b] | 43 | 13.0 |
| [illegible] | 393118 | 743514 | 07/01/87 | 100 | 4.5 | <1[b] | 52 | 15.0 |
| [illegible] | 392658 | 743751 | 10/11/84 | 64 | 4.9 | 4[b] | 3 | 14.5 |
| [illegible] | 392710 | 744440 | 09/18/85 | 347 | 8.0 | 69 | 60 | 14.5 |
| [illegible] | 392714 | 744328 | 04/24/69 | 226 | 8.2 | 61 | 55 | 15.0 |
| [illegible] | 392724 | 743824 | 09/18/85 | 151 | 5.2 | 4[b] | 1 | 13.0 |
| [illegible] | 393047 | 744114 | 10/11/84 | 55 | 4.7 | 2[b] | 1 | 16.0 |
| [illegible] | 393303 | 744413 | 10/11/84 | 157 | 4.5 | 1[b] | 1 | 15.0 |
| [illegible] | 393333 | 744426 | 10/23/85 | 275 | 6.2 | 15 | 4 | 13.0 |
| [illegible] | 393748 | 744836 | 05/19/64 | 98 | 5.4 | 2 | 7 | -- |
| [illegible] | 393758 | 744853 | 02/18/86 | 315 | 4.5 | <1 | 4 | 13.5 |
| [illegible] | 393815 | 744728 | 09/04/85 | 100[a] | 4.5 | <1 | 19 | 16.0 |
| [illegible] | 393827 | 744508 | 07/02/87 | 58[a] | 5.1 | 1 | 14 | 13.5 |
| [illegible] | 393821 | 744006 | 07/02/87 | 96[a] | 4.4 | <1[b] | 1 | 13.0 |
| [illegible] | 393927 | 744602 | 02/05/86 | 65[a] | 5.8 | <1 | 19 | 13.0 |
| [illegible] | 394138 | 744119 | 04/28/78 | 20 | 3.8 | <1 | 3 | 11.5 |
| [illegible] | 394316 | 744415 | 11/12/85 | 15 | 4.4 | <1 | 5 | 15.0 |
| [illegible] | 394041 | 744604 | 02/16/78 | 150 | 4.2 | <1 | 2 | 13.5 |
| [illegible] | 394108 | 744319 | 03/31/78 | 22 | 4.8 | 3 | 2 | 11.5 |
| [illegible] | 394156 | 744508 | 04/16/85 | 25 | 4.5 | <1 | 3 | 14.0 |
| [illegible] | 392001 | 743522 | 08/20/68 | 71 | 5.6 | 7 | 4 | 11.5 |
| [illegible] | 393333 | 744427 | 04/24/69 | 176 | 6.3 | 2 | 1 | -- |
| [illegible] | 393359 | 744056 | 09/05/85 | 176 | 4.3 | <1 | 7 | 13.5 |
| [illegible] | 393447 | 744245 | 10/03/85 | 80 | 5.2 | 5 | 2 | 14.5 |
| [illegible] | 393557 | 744114 | 06/21/84 | 136[a] | 5.5 | 7 | 2 | 12.5 |
| [illegible] | 393604 | 744459 | 09/05/85 | 108 | 5.0 | 4 | 3 | 14.0 |
| [illegible] | 393638 | 743808 | 07/26/85 | 91 | 5.1 | 3 | 1 | 13.0 |
| [illegible] | 393743 | 743859 | 04/24/69 | 67[a] | 4.4 | <1 | 2 | 13.5 |
| [illegible] | 392157 | 743317 | 04/22/64 | 152 | 5.2 | 3 | 7 | 13.0 |
| [illegible] | 392440 | 743035 | 04/28/64 | 208 | 4.8 | 2 | 4 | 10.0 |
| [illegible] | 392442 | 743051 | 04/28/64 | 90 | 5.1 | 2 | 8 | 10.0 |
| [illegible] | 392510 | 743033 | 04/28/64 | 92 | 5.2 | 2 | 4 | 10.0 |
| [illegible] | 392510 | 743031 | 04/28/64 | 195 | 4.8 | 2 | 6 | 10.0 |
| [illegible] | 392548 | 743119 | 10/17/85 | 195 | 5.8 | 9 | 6 | 13.0 |
| [illegible] | 392428 | 744953 | 10/03/85 | 57 | 4.6 | 4 | 1 | 14.0 |
| [illegible] | 391826 | 744620 | 10/29/85 | 111[a] | 6.0 | 12 | <1 | 13.5 |
| [illegible] | 393733 | 744908 | 07/23/87 | 62[a] | 4.8 | 0 | 9 | 14.5 |
| [illegible] | 393856 | 744939 | 10/17/85 | 80 | 5.0 | 3 | 2 | 14.5 |
| [illegible] | 393059 | 745850 | 11/01/85 | 160 | 4.8 | 3 | 7 | 13.5 |
| [illegible] | 393631 | 744840 | 07/08/87 | 100 | 4.9 | 2 | 7 | 14.0 |

[illegible]nnotes at end of table.

Table 5.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Atlantic County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 1.2 | 45 | 8.2 | 9.0 | U | -- | 5.7 | 11 | 010013 |
| 46 | 272 | 36 | 36 | A | -5.4 | 6.5 | 88 | 010044 |
| 6.1 | 75 | 9.9 | .70 | A | -5.5 | 6.3 | 7.4 | 010069 |
| 2.0 | 40 | 4.3 | 15 | A | -6.2 | 5.6 | 11 | 010074 |
| 13 | 92 | 13 | 25 | F | -5.7 | 6.1 | 44 | 010094 |
| 7.6 | 130 | 38 | 12 | F | -6.1 | 5.7 | 66 | 010109 |
| 2.8 | 40 | 10 | 5.7 | F | -5.6 | 6.2 | 6.7 | 010134 |
| 2.7 | 40 | 9.2 | 2.4 | F | -6.0 | 5.8 | 7.7 | 010135 |
| .91 | 8 | 5.8 | 1.6 | F | -5.6 | 6.2 | 2.5 | 010136 |
| .63 | 22 | 8.2 | 1.8 | F | -6.1 | 5.7 | 4.5 | 010138 |
| .36 | 20 | 5.1 | 2.4 | F | -6.1 | 5.6 | 3.2 | 010154 |
| .48 | 12 | 2.3 | .20 | F | -5.7 | 6.1 | .9 | 010163 |
| 2.0 | 42 | 4.4 | .60 | A | -5.6 | 6.2 | 2.3 | 010169 |
| .60 | 32 | 7.3 | 5.2 | F | -6.5 | 5.3 | 7.9 | 010172 |
| .13 | 24 | 7.4 | 2.2 | U | -6.7 | 5.1 | 4.3 | 010179 |
| .26 | 35 | 17 | .50 | U | -6.4 | 5.4 | 6.1 | 010181 |
| .61 | 27 | 6.7 | 4.9 | F | -6.6 | 5.2 | 7.3 | 010185 |
| .47 | 29 | 5.7 | 4.4 | F | -6.7 | 5.1 | 6.3 | 010193 |
| 4.9 | 78 | 13 | .20 | F | -5.0 | 6.8 | 6.2 | 010198 |
| 14 | 72 | 18 | 31 | F | -5.8 | 6.0 | 58 | 010201 |
| 17 | 150 | 16 | 29 | F | -5.8 | 6.1 | 53 | 010202 |
| 21 | 165 | 29 | 32 | F | -5.6 | 6.2 | 74 | 010206 |
| 1.0 | 65 | 43 | .5 | F | -5.9 | 5.9 | 15 | 010226 |
| 24 | 124 | 5.7 | 10 | F | - .2 | 11.6 | .3 | 010227 |
| 22 | 121 | 4.3 | 11 | U | - .1 | 11.7 | .3 | 010229 |
| .25 | 17 | 5.1 | 1.0 | U | -6.2 | 5.6 | 2.1 | 010232 |
| .42 | 49 | 28 | .30 | F | -6.7 | 5.0 | 20 | 010244 |
| .40 | 11 | 3.2 | 3.7 | F | -7.2 | 4.5 | 8.4 | 010250 |
| 1.5 | 32 | .2 | 12 | F | -3.8 | 7.9 | .9 | 010256 |
| 2.8 | 68 | 9.6 | .60 | U | -- | 6.5 | 7.1 | 010278 |
| 1.4 | 30 | 3.8 | 4.7 | U | -6.8 | 5.0 | 10 | 010279 |
| 7.7 | 71 | 9.7 | 19 | U | -6.0 | 5.8 | 34 | 010286 |
| 5.5 | 52 | 15 | 5.6 | A | -5.6 | 6.2 | 27 | 010288 |
| .39 | 20 | 2.8 | 10 | F | -7.4 | 4.4 | 14 | 010290 |
| 7.6 | 68 | 9.8 | 14 | A | -4.8 | 7.1 | 28 | 010325 |
| 1.0 | 48 | 5.2 | 13 | F | -7.6 | 4.2 | 21 | 010344 |
| 1.8 | 31 | 6.1 | 15 | F | -6.7 | 5.1 | 24 | 010348 |
| .80 | 28 | 3.5 | 12 | U | -7.3 | 4.5 | 17 | 010349 |
| .90 | 24 | 1.8 | 11 | F | -6.2 | 5.6 | 4.7 | 010351 |
| 1.3 | 26 | 6.3 | 13 | F | -6.8 | 5.0 | 22 | 010352 |
| 1.6 | 67 | 12 | 3.2 | | -4.8 | 7.0 | 2.9 | 010353 |
| .40 | 18 | 4.5 | 1.1 | U | -- | 6.6 | 3.8 | 010377 |
| 2.6 | 48 | 7.0 | 19 | F | -6.7 | 5.1 | 30 | 010378 |
| .73 | 18 | 6.5 | .20 | F | -5.6 | 6.2 | 1.9 | 010383 |
| .85 | 18 | 4.0 | 1.5 | F | -5.1 | 6.7 | 1.0 | 010387 |
| 1.2 | 46 | 16 | .20 | F | -5.7 | 6.1 | 5.7 | 010388 |
| .47 | 38 | 4.4 | 6.5 | F | -6.2 | 5.6 | 4.3 | 010391 |
| .80 | 44 | 4.1 | 10 | F | -7.1 | 4.7 | 16 | 010405 |
| 2.8 | 59 | 11 | 9.2 | | -5.3 | 6.5 | 8.4 | 010549 |
| 1.6 | 49 | 5.8 | 11 | U | -6.2 | 5.7 | 9.8 | 010567 |
| 3.2 | 70 | 19 | 11 | U | -5.6 | 6.3 | 19 | 010569 |
| 1.6 | 61 | 14 | 2.0 | U | -5.8 | 6.1 | 11 | 010573 |
| 2.4 | 51 | 7.1 | 12 | U | -6.0 | 5.9 | 11 | 010574 |
| 2.4 | 48 | 5.4 | 9.1 | F | -4.3 | 7.5 | 1.9 | 010575 |
| .31 | 14 | 3.8 | .40 | U | -6.8 | 5.1 | 1.5 | 010601 |
| .02 | 49 | 4.1 | 7.1 | F | -6.0 | 5.8 | 1.1 | 010604 |
| 3.6 | 54 | 10 | .50 | A | -6.1 | 5.8 | 14 | 010611 |
| .94 | 30 | 5.4 | 6.4 | A | -5.9 | 5.8 | 4.8 | 010628 |
| 2.9 | 44 | 5.4 | 2.2 | A | -5.7 | 6.1 | 3.3 | 010639 |
| 2.6 | 45 | 8.9 | .20 | A | -5.8 | 6.0 | 6.4 | 010640 |

Table 5.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Atlantic County, New Jersey--Continued

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft below LSD) | pH (standard units) | Alkalinity (mg/L as $CaCO_3$) | Calcium hardness (mg/L as $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 010655 | 393627 | 745029 | 07/10/87 | 98 | 5.3 | 4 | 4 | 12.5 |
| 010699 | 392933 | 744604 | 02/10/86 | 160 | 8.0 | 74 | 70 | 12.5 |
| 010712 | 392902 | 745051 | 10/10/85 | 387 | 6.2 | 23 | 18 | 13.5 |
| 010718 | 391957 | 744657 | 11/13/85 | 26 | 4.9 | 2 | 2 | 13.5 |
| 010719 | 393241 | 744818 | 11/13/85 | 38 | 5.1 | 3 | 1 | 14.0 |
| 010721 | 393145 | 743009 | 11/14/85 | 26 | 4.5 | <1 | 24 | 15.5 |
| 010731 | 393220 | 743530 | 11/25/85 | 105 | 5.0 | 3 | 3 | 13.0 |
| 010732 | 392201 | 743400 | 10/24/85 | 95 | 4.9 | 2 | 2 | 13.5 |
| 010739 | 391850 | 744818 | 11/26/85 | 102 | 4.5 | <1 | 2 | 14.0 |
| 010763 | 392658 | 744731 | 11/19/85 | 60 | 4.9 | 3 | 0 | 13.0 |
| 010764 | 392216 | 743758 | 02/26/86 | 114 | 5.3 | 3 | 1 | 11.0 |
| 010765 | 393351 | 743230 | 11/25/85 | 81 | 5.1 | 2 | 2 | 13.0 |
| 010766 | 392130 | 744142 | 10/30/85 | 140 | 5.3 | 4 | 1 | 13.5 |
| 010767 | 391949 | 743854 | 11/21/85 | 126 | 5.0 | 3 | 4 | 14.0 |
| 010768 | 392247 | 743500 | 10/25/85 | 112 | 5.4 | 6 | 2 | 13.0 |
| 010770 | 392241 | 744933 | 11/15/85 | 70 | 4.7 | 4 | 1 | 14.5 |
| 010771 | 392113 | 743223 | 12/17/85 | 120 | 5.3 | 4 | 2 | 13.0 |
| 010774 | 392457 | 744355 | 02/06/86 | 180 | 8.2 | 80 | 65 | 13.0 |
| 010775 | 392639 | 743232 | 10/11/85 | 182 | 4.5 | <1 | 2 | 13.0 |
| 010776 | 392639 | 743232 | 10/11/85 | 93 | 4.7 | 1 | 1 | 12.5 |
| 010793 | 393149 | 745554 | 08/26/87 | 106 | 5.5 | 7 | 25 | 15.0 |
| 010833 | 392959 | 744107 | 10/18/84 | 80 | 5.1 | 3[b] | <1 | 13.5 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5-minute series topographic maps and well records used for confirmation.

a Number is depth of well. Depth to bottom of screen not reported.

b Field value not reported; laboratory value used.

Table 5.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Atlantic County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 1.6 | 38 | 4.5 | 4.9 | A | -5.4 | 6.5 | 2.9 | 010655 |
| 28 | 139 | 2.3 | 8.8 | F | - .1 | 11.7 | .2 | 010699 |
| 7.1 | 64 | 3.2 | 11 | F | -3.0 | 8.8 | .7 | 010712 |
| .85 | 21 | 4.5 | 4.9 | F | -6.3 | 5.5 | 5.7 | 010718 |
| .23 | 12 | 3.1 | 1.3 | F | -6.4 | 5.3 | 1.9 | 010719 |
| 9.6 | 71 | 10 | 23 | F | -5.9 | 5.9 | 38 | 010721 |
| 1.3 | 23 | 5.4 | 4.6 | F | -5.8 | 6.0 | 4.1 | 010731 |
| .66 | 55 | 12 | 1.8 | U | -6.4 | 5.4 | 9.4 | 010732 |
| .70 | 31 | 3.3 | 9.1 | F | -7.0 | 4.7 | 14 | 010739 |
| .13 | 11 | 3.7 | .40 | F | -6.9 | 4.9 | 1.9 | 010763 |
| .40 | 15 | 5.2 | .60 | | -6.0 | 5.8 | 2.7 | 010764 |
| .60 | 19 | 4.4 | 1.8 | F | -6.2 | 5.6 | 4.0 | 010765 |
| .46 | 25 | 4.7 | 2.0 | F | -5.8 | 6.0 | 2.2 | 010766 |
| 1.6 | 45 | 9.8 | 7.5 | F | -5.7 | 6.1 | 7.2 | 010767 |
| .85 | 24 | 5.7 | 1.8 | A | -5.3 | 6.5 | 1.7 | 010768 |
| .43 | 45 | 13 | .10 | U | -6.4 | 5.3 | 4.6 | 010770 |
| .90 | 31 | 11 | 1.6 | F | -5.5 | 6.3 | 4.3 | 010771 |
| 26 | -- | 2.5 | 7.9 | F | -- | 11.9 | .2 | 010774 |
| .74 | 36 | 4.3 | 8.0 | F | -7.0 | 4.8 | 14 | 010775 |
| .40 | 26 | 5.8 | 1.4 | F | -7.1 | 4.7 | 9.7 | 010776 |
| 9.8 | 110 | 13 | 11 | A | -4.0 | 7.7 | 4.3 | 010793 |
| .11 | 10 | 3.6 | .3 | F | -6.7 | 5.0 | 1.8 | 010833 |

Table 6.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Burlington County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of .4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 050001 | 393533 | 742635 | 08/14/51 | 232[a] | 4.7[b] | 2[c] | 3 | 13.5 |
| 050003 | 393731 | 742531 | 08/14/51 | 88[a] | 5.0[b] | 2[c] | 3 | 13.5 |
| 050012 | 393945 | 743126 | 08/14/51 | 375[a] | 4.7[b] | <1[c] | 2 | 13.5 |
| 050019 | 394050 | 743037 | 05/13/85 | 25 | 4.8 | 2 | 2 | 13.0 |
| 050024 | 394143 | 742828 | 03/29/78 | 35 | 4.7 | 1 | 2 | 12.0 |
| 050029[d] | 394208 | 742645 | 09/07/84 | 59[a] | 6.7 | 10 | 1 | 12.5 |
| 050030[d] | 394208 | 742645 | 03/14/62 | 345 | 7.3[b] | 44[c] | 7 | 11.5 |
| 050034 | 394312 | 742821 | 03/29/78 | 44 | 5.1 | 3 | 5 | 13.0 |
| 050399 | 394520 | 744511 | 04/12/85 | 25 | 5.0 | 1 | 13 | 14.0 |
| 050404 | 394406 | 744127 | 04/16/85 | 35 | 4.7 | 1 | 2 | 12.5 |
| 050408[d] | 394422 | 744309 | 06/01/83 | 65 | 6.6 | 14 | 1 | 12.5 |
| 050409 | 394422 | 744309 | 09/06/84 | 17 | 4.7 | 1 | 5 | 16.0 |
| 050411 | 394434 | 744342 | 08/14/51 | 88[a] | 5.5[b] | 2[c] | 1 | 15.0 |
| 050415 | 394531 | 744356 | 04/15/85 | 26 | 4.8 | 2 | 4 | 11.5 |
| 050417[d] | 394608 | 744054 | 09/03/81 | 100 | 6.9 | 67 | 1 | 13.0 |
| 050418 | 394608 | 744054 | 04/15/85 | 46 | 4.7 | 2 | 1 | 12.0 |
| 050421 | 394738 | 744439 | 06/21/51 | 60[a] | 4.3[b] | 1[c] | 3 | 14.5 |
| 050422 | 394834 | 744715 | 02/17/78 | 26 | 5.2 | 2 | 2 | 10.5 |
| 050451[d] | 394536 | 743542 | 08/23/84 | 170 | 7.3 | 88 | 62 | 13.5 |
| 050452 | 394536 | 743542 | 07/19/84 | 21 | 5.8 | 1 | 2 | 15.5 |
| 050453 | 394636 | 743739 | 04/21/78 | 19 | 4.4 | 1 | 4 | 10.0 |
| 050454[d] | 394812 | 744031 | 09/28/83 | 142 | 6.4 | 16 | 8 | 12.5 |
| 050455 | 394812 | 744031 | 09/28/83 | 51 | 4.8 | 5 | 2 | 13.5 |
| 050457 | 394848 | 743656 | 04/21/78 | 30 | 4.3 | 1 | 7 | 11.0 |
| 050468 | 393650 | 743427 | 06/21/51 | 73[a] | 5.5[b] | 4[c] | 6 | 18.5 |
| 050477 | 393748 | 743817 | 04/27/78 | 25 | 4.6 | 1 | 1 | 9.5 |
| 050482 | 393809 | 743349 | 09/28/83 | 25 | 4.3 | 1 | 2 | 17.5 |
| 050485 | 393832 | 743608 | 04/14/78 | 250 | 5.1 | 2 | 2 | 12.0 |
| 050502 | 393944 | 743714 | 03/09/78 | 25 | 5.1 | 2 | 4 | 5.5 |
| 050503 | 393945 | 743848 | 03/09/78 | 40 | 4.8 | 1 | 2 | 10.5 |
| 050511[d] | 394009 | 743252 | 09/23/83 | 250 | 4.8[b] | 5[b] | 1 | 12.5 |
| 050512 | 394009 | 743252 | 09/23/83 | 50 | 4.4 | 1 | 1 | 12.0 |
| 050568 | 394104 | 743440 | 04/12/78 | 25 | 4.8 | 2 | 1 | 11.0 |
| 050592 | 394208 | 744031 | 03/08/78 | 25 | 4.3 | 1 | 3 | 9.5 |
| 050598[d] | 394223 | 744153 | 04/28/78 | 150 | 5.4 | 6 | 4 | 13.0 |
| 050599 | 394223 | 744153 | 04/28/78 | 25 | 5.0 | 4 | 3 | 12.0 |
| 050600 | 394226 | 743948 | 03/08/78 | 25 | 4.3 | 1 | 3 | 10.0 |
| 050608[d] | 394300 | 743830 | 08/09/84 | 160 | 5.0 | 4 | <1 | 13.5 |
| 050609 | 394300 | 743830 | 08/09/84 | 45 | 5.1 | 2 | 3 | 13.0 |
| 050612[d] | 394305 | 743357 | 07/19/84 | 272 | 5.4 | 1 | 2 | 13.5 |
| 050613 | 394305 | 743357 | 08/23/84 | 35 | 4.9 | 4 | 1 | 13.0 |
| 050615 | 394312 | 743213 | 06/13/61 | 30[a] | 4.8[b] | 2[c] | 4 | 20.5 |
| 050618 | 394329 | 743718 | 04/06/78 | 25 | 4.6 | 1 | 5 | 10.0 |
| 050625 | 394405 | 743958 | 05/13/85 | 20 | 5.4 | 1 | 2 | 19.5 |
| 050628 | 394452 | 742819 | 06/13/84 | 12[a] | 7.0 | 12 | 9 | 22.0 |
| 050675 | 394907 | 743207 | 05/02/51 | 63[a] | 6.5 | 11 | 1 | 16.5 |
| 050684 | 395122 | 743017 | 06/19/84 | 170 | 4.7 | 1 | 1 | 12.5 |
| 050690 | 395211 | 743103 | 02/22/64 | 81 | 5.2[b] | 3[c] | 1 | 8.5 |
| 050698 | 395413 | 742805 | 08/06/58 | 95[a] | 6.1[b] | <1[c] | <1 | 11.5 |
| 050765 | 395513 | 743020 | 11/26/60 | 23[a] | 4.3[b] | 1[c] | 1 | 14.0 |
| 050769 | 395247 | 742927 | 08/13/58 | 34 | 5.4[b] | 2[c] | 4 | 10.5 |
| 050835 | 395245 | 742952 | 09/30/87 | 17 | 4.5 | <1 | 3 | 14.0 |
| 050842 | 395301 | 742953 | 02/25/86 | 37 | 5.0 | <1 | 2 | 11.5 |
| 050851 | 395217 | 742937 | 02/25/86 | 30 | 4.8 | <1 | 4 | 11.0 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

a Number is depth of well. Depth to bottom of screen is not recorded for these wells.

b Field value not reported; laboratory value used.

c Alkalinity calculated from bicarbonate alkalinity value.

d Well is deeper of pair of nested piezometers, and is not plotted on pl. 1.

Table 6.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Burlington County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 1.0 | 54 | 3.6 | 7.0 | F | -6.4 | 5.4 | 6.2 | 050001 |
| 1.3 | 26 | 8.2 | 4.5 | F | -6.0 | 5.8 | 8.1 | 050003 |
| .80 | 49 | 3.1 | 10 | F | -6.9 | 5.0 | 18 | 050012 |
| .87 | 28 | 4.1 | 7.1 | F | -6.4 | 5.4 | 6.6 | 050019 |
| .60 | 16 | 3.6 | 7.7 | F | -6.9 | 4.9 | 13 | 050024 |
| .50 | 20 | 3.5 | .3 | F | -4.0 | 7.8 | .5 | 050029[d] |
| 2.9 | 80 | 5.6 | 16 | F | -2.0 | 9.8 | .6 | 050030[d] |
| 1.9 | 28 | 3.8 | 10 | F | -5.5 | 6.3 | 5.3 | 050034 |
| 5.3 | 40 | 10 | 11 | F | -5.7 | 6.1 | 26 | 050399 |
| .81 | 21 | 2.6 | 5.7 | F | -6.8 | 5.0 | 9.6 | 050404 |
| .53 | 40 | 3.1 | 42 | F | -3.9 | 7.9 | 3.4 | 050408[d] |
| 2.1 | -- | 9.1 | 8.8 | F | -- | 5.4 | 22 | 050409 |
| .20 | 16 | 4.2 | .0 | U | -6.2 | 5.5 | 3.0 | 050411 |
| 1.6 | 22 | 2.7 | 7.9 | F | -6.1 | 5.7 | 6.0 | 050415[d] |
| .70 | -- | 1.6 | 3.8 | F | -- | 9.0 | .1 | 050417[d] |
| .32 | 18 | 2.5 | 3.4 | F | -6.9 | 4.9 | 3.5 | 050418 |
| 1.2 | 29 | 8.5 | 7.5 | F | -7.0 | 4.8 | 20 | 050421 |
| .70 | 10 | 3.3 | 1.6 | F | -6.1 | 5.7 | 3.2 | 050422[d] |
| 25 | 140 | 1.7 | 7.5 | F | -0.8 | 11.0 | .1 | 050451[d] |
| .62 | 31 | 3.2 | 4.3 | F | -5.8 | 6.0 | 9.0 | 050452 |
| 1.5 | 24 | 4.4 | 13 | F | -6.9 | 5.0 | 20 | 050453[d] |
| 3.3 | 52 | 2.0 | 6.1 | F | -3.3 | 8.5 | .6 | 050454[d] |
| .83 | 22 | 3.5 | 4.5 | F | -6.0 | 5.8 | 1.9 | 050455 |
| 3.0 | 46 | 7.7 | 22 | F | -6.7 | 5.2 | 34 | 050457 |
| 2.4 | 25 | 5.0 | 4.2 | F | -4.8 | 6.9 | 2.7 | 050468 |
| .30 | 50 | 11 | 9.3 | F | -7.4 | 4.5 | 25 | 050477 |
| .98 | 34 | 9.0 | 14 | F | -7.0 | 4.7 | 27 | 050482 |
| .80 | 32 | 2.2 | 8.1 | F | -6.1 | 5.7 | 5.8 | 050485 |
| 1.4 | 23 | 2.3 | 8.4 | F | -6.0 | 5.9 | 6.0 | 050502 |
| .80 | 18 | 2.7 | 4.8 | F | -6.7 | 5.1 | 8.8 | 050503 |
| .33 | 31 | 3.0 | 5.6 | F | -6.4 | 5.4 | 2.0 | 050511[d] |
| .33 | 24 | 3.2 | 13 | F | -7.5 | 4.3 | 18 | 050512 |
| .50 | 16 | 2.2 | 8.7 | F | -6.6 | 5.2 | 6.1 | 050568 |
| 1.0 | 20 | 1.9 | 9.1 | F | -7.1 | 4.7 | 12 | 050592 |
| 1.7 | 21 | 2.7 | 2.5 | F | -5.0 | 6.8 | 1.1 | 050598[d] |
| 1.2 | 20 | 1.7 | 7.9 | F | -5.7 | 6.1 | 2.7 | 050599 |
| 1.2 | 22 | 2.4 | 8.4 | F | -7.1 | 4.8 | 12 | 050600 |
| .17 | 20 | 2.8 | .50 | F | -6.5 | 5.2 | 1.1 | 050608[d] |
| 1.2 | 25 | 3.1 | 7.1 | F | -5.9 | 5.9 | 5.9 | 050609 |
| .90 | 19 | 3.2 | 2.7 | F | -6.0 | 5.8 | 7.3 | 050612[d] |
| .49 | 14 | 2.8 | 3.2 | F | -6.2 | 5.6 | 1.8 | 050613 |
| 1.6 | 23 | 2.2 | 6.7 | A | -6.1 | 5.7 | 6.2 | 050615 |
| 2.0 | 18 | 3.9 | 8.4 | F | -6.5 | 5.3 | 14 | 050618 |
| .89 | 31 | 2.9 | 5.6 | F | -5.9 | 5.7 | 9.9 | 050625 |
| 3.4 | 44 | 3.6 | 3.6 | F | -2.7 | 9.0 | .7 | 050628 |
| .5 | 22 | 2.8 | 2.0 | U | -4.1 | 7.6 | .5 | 050675 |
| .41 | 26 | .10 | 10 | F | -7.1 | 4.7 | 11 | 050684 |
| .40 | 22 | 3.2 | .20 | F | -6.1 | 5.7 | 1.4 | 050690 |
| .0 | 15 | 3.2 | 1.0 | F | -- | 4.5 | 6.8 | 050698 |
| .40 | 22 | 3.6 | 5.9 | F | -7.5 | 4.3 | 11 | 050765 |
| 1.6 | 25 | 3.5 | 7.9 | F | -5.5 | 6.3 | 6.6 | 050769 |
| 1.1 | -- | 3.8 | 9.6 | F | -- | 4.9 | 31 | 050835 |
| .70 | -- | 3.2 | 3.6 | F | -- | 5.2 | 14 | 050842 |
| 1.6 | -- | 3.8 | 8.1 | F | -- | 5.4 | 28 | 050851 |

Table 7.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Camden County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) | Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | LSI | AI | LI |
| 070429 | 394148 | 744810 | 03/31/78 | 19 | 4.4 | <1 | 2 | 9.5 | 0.60 | 23 | 2.1 | 8.8 | F | -7.3 | 4.6 | 12 |
| 070430[a] | 394204 | 744921 | 07/17/84 | 120 | 5.0 | <1 | 1 | 13.0 | .36 | 42 | 2.9 | 2.2 | F | -6.9 | 5.0 | 6.4 |
| 070431 | 394204 | 744921 | 03/10/78 | 29 | 4.7 | 2 | 9 | 10.5 | 3.5 | 30 | 3.7 | 10 | F | -5.9 | 5.9 | 7.8 |
| 070432 | 394224 | 744713 | 02/23/78 | 25 | 4.8 | 1 | 7 | 10.0 | 2.8 | 25 | .2 | 8.5 | F | -6.2 | 5.6 | 9.1 |
| 070440 | 394431 | 744941 | 02/23/78 | 24 | 5.6 | 1 | 20 | 10.0 | 7.8 | 63 | 8.1 | 18 | F | -5.0 | 6.9 | 30 |
| 070441 | 394438 | 744838 | 04/25/78 | 25 | 4.4 | <1 | 4 | 11.0 | 1.7 | 23 | 3.5 | 13 | F | -6.8 | 5.0 | 19 |
| 070442 | 394455 | 745043 | 05/16/85 | 24 | 4.5 | <1 | 3 | 13.0 | 1.1 | 22 | 2.7 | 10 | F | -6.8 | 4.9 | 14 |
| 070444 | 394553 | 744739 | 03/15/78 | 26 | 4.2 | <1[b] | 3 | 10.5 | 1.1 | 18 | 1.8 | 9.7 | F | -7.2 | 4.6 | 13 |
| 070451 | 394628 | 744923 | 07/17/84 | 166 | 5.4[b] | <1[b] | 3 | 13.0 | 1.2 | 56 | 1.6 | 6.0 | F | -5.9 | 5.9 | 8.5 |
| 070493 | 394311 | 745707 | 08/20/74 | 78 | 4.6[b] | 5[b] | 6 | 13.0 | 2.6 | 40 | 6.0 | 1.7 | F | -5.7 | 6.1 | 2.1 |
| 070503 | 394440 | 745931 | 08/22/86 | 76 | 5.5 | 4 | <1 | 11.5 | .10 | 14 | 2.3 | .70 | F | -6.3 | 5.5 | 1.0 |
| 070603 | 394414 | 750016 | 07/24/85 | 120 | 5.0 | 4 | 18 | 14.0 | 7.2 | 81 | 15 | 9.5 | A | -5.0 | 6.9 | 7.8 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

a Well is deeper of pair of nested piezometers, and is not plotted on pl. 1.

b Field value not reported; laboratory value used.

Table 8.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Cumberland County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) | Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | LSI | AI | LI |
| 110015 | 392555 | 751415 | 07/09/75 | 77 | 5.8 | <1 | 8 | 14.5 | 3.0 | 48 | 11 | 13 | U | -5.1 | 6.7 | 29 |
| 110042 | 392732 | 750929 | 05/13/86 | 47 | 5.3 | 2 | 3 | 13.5 | 1.0 | 25 | 4.3 | .7 | F | -5.8 | 6.0 | 3.4 |
| 110043[c] | 392732 | 750929 | 05/12/86 | 138 | 5.1 | 2 | 8 | 13.5 | 3.3 | 54 | 7.7 | 1.5 | F | -5.5 | 6.3 | 6.2 |
| 110073 | 392508 | 751846 | 07/29/86 | 40 | 6.3 | 18 | 35 | 12.0 | 14 | 84 | 8.2 | 20 | F | -2.7 | 9.1 | 1.8 |
| 110083 | 392837 | 751735 | 06/30/87 | 69 | 5.3 | 6 | 43 | 14.0 | 17 | 153 | 23 | 36 | A | -4.1 | 7.7 | 12 |
| 110093 | 391832 | 751244 | 08/11/87 | 62 | 5.0 | 2[b] | 122 | 18.0 | 49 | 316 | 30 | 110 | F | -4.5 | 7.4 | 79 |
| 110097 | 391829 | 751208 | 09/22/86 | 171 | 7.9 | 86 | 85 | 13.5 | 34 | 146 | 3.0 | 16 | F | -0.1 | 1.8 | .2 |
| 110100 | 391840 | 751336 | 08/11/87 | 74 | 5.2 | 2[b] | 195 | 14.0 | 78 | 490 | 42 | 160 | A | -4.1 | 7.8 | 110 |
| 110119 | 391350 | 750018 | 06/07/78 | 135 | 7.1 | 55 | 40 | 15.0 | 16 | 128 | 1.9 | 9.9 | F | -1.4 | 0.4 | .2 |
| 110161 | 392526 | 750643 | 06/26/84 | 176 | 5.2 | 5 | 2 | 13.5 | .79 | 38 | 2.4 | 5.1 | F | -5.6 | 6.2 | 1.7 |
| 110237 | 392920 | 745700 | 11/15/84 | 81 | 5.4 | 2 | 9 | 14.0 | 3.6 | 54 | 7.9 | .4 | A | -5.1 | 6.7 | 5.8 |
| 110252 | 392957 | 750019 | 10/02/63 | 175 | 5.0 | 3 | 13 | 13.0 | 5.2 | 43 | 6.4 | .0 | U | -5.2 | 6.6 | 3.0 |
| 110287 | 392831 | 751820 | 06/30/87 | 90 | 4.9 | 2 | 35 | 15.5 | 14 | 145 | 27 | 31 | A | -5.0 | 6.7 | 35 |
| 110289 | 392813 | 745636 | 06/29/87 | 60 | 4.7 | 2 | 72 | 14.5 | 29 | 234 | 22 | 19 | A | -5.0 | 6.9 | 25 |
| 110322 | 392337 | 750218 | 07/09/75 | 110[a] | 5.5 | <1 | 5 | 15.0 | 1.9 | 51 | 4.9 | 16 | U | -5.6 | 6.2 | 23 |
| 110360 | 392027 | 751507 | 07/06/87 | 60[a] | 4.4 | <1[b] | 95 | 14.0 | 38 | 250 | 25 | 63 | F | -5.5 | 6.4 | 100 |
| 110367 | 392933 | 751708 | 08/05/87 | 70[a] | 5.1 | 3[b] | 55 | 12.5 | 22 | 210 | 25 | 29 | A | -4.6 | 7.3 | 22 |
| 110369 | 392450 | 751539 | 09/01/87 | 126[a] | 4.7 | 0 | 17 | 14.0 | 6.7 | 82 | 11 | 17 | A | -5.9 | 5.9 | 33 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

a Number is depth of well. Depth to bottom of screen not reported for these wells.

b Field value not reported; laboratory value used.

c Well is deeper of pair of nested piezometers, and is not plotted on pl. 1.

Table 9.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Gloucester County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 150002 | 393914 | 750519 | 04/23/51 | 105 | 5.2[b] | 6[b] | 12 | 13.5 |
| 150038 | 394057 | 751007 | 05/29/57 | 45 | 5.7[b] | 3[b] | 7 | 15.5 |
| 150041 | 393149 | 745752 | 07/21/87 | 68[a] | 4.6 | 1 | 70 | 17.0 |
| 150046 | 393410 | 745630 | 05/30/57 | 96[a] | 5.3[b] | 2[b] | 3 | 14.5 |
| 150048 | 393446 | 745606 | 11/19/86 | 120 | 4.6[b] | 3[b] | 28 | 13.5 |
| 150053 | 393634 | 750419 | 06/04/57 | 90 | 6.2[b] | 21[b] | 9 | 15.5 |
| 150057 | 393751 | 750107 | 06/04/57 | 58[a] | 5.2[b] | 2[b] | 5 | 13.0 |
| 150209 | 393254 | 750121 | 11/20/86 | 162 | 4.6 | 2[b] | 4 | 13.5 |
| 150244 | 394235 | 750427 | 07/08/87 | 100 | 4.7 | 4 | 9 | 13.5 |
| 150246 | 394315 | 750147 | 05/30/57 | 50 | 6.2[b] | 11[b] | 5 | 15.5 |
| 150258 | 394516 | 750421 | 05/29/57 | 60 | 5.7[b] | 5[b] | 12 | 15.0 |
| 150365 | 394203 | 745936 | 11/20/86 | 143 | 4.3 | <1[b] | 5 | 13.0 |
| 150375 | 394010 | 745845 | 11/20/86 | 147 | 4.5 | 2[b] | 8 | 13.0 |
| 150424 | 393254 | 750119 | 04/23/51 | 134 | 6.4[b] | 4[b] | 3 | 13.0 |
| 150425 | 394047 | 745927 | 04/23/51 | 132 | 4.8[b] | 1[b] | 7 | 13.0 |
| 150426 | 394052 | 745930 | 04/23/51 | 105[a] | 4.9[b] | 3[b] | 9 | -- |
| 150726 | 394130 | 750921 | 11/19/86 | 62 | 5.0 | 5[b] | 65 | 14.5 |
| 150729 | 393331 | 750154 | 11/19/86 | 80 | 4.3 | <1[b] | 23 | 13.0 |
| 150730 | 393154 | 745811 | 07/30/87 | 98 | 4.6 | 1 | 77 | 13.5 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

a Number is depth of well. Depth to bottom of screen not reported for these wells.

b Field value not reported; laboratory value used.

Table 9.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Gloucester County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 4.6 | 121 | 18 | 12 | U | -4.8 | 7.4 | 6.3 | 150002 |
| 2.6 | 57 | 6.1 | .40 | A | -4.8 | 7.0 | 3.0 | 150038 |
| 28.0 | 217 | 21 | 47 | A | -5.3 | 6.4 | 78.6 | 150041 |
| 1.3 | 62 | 7.0 | .20 | A | -5.7 | 6.1 | 5.0 | 150046 |
| 11.0 | -- | 9.4 | 21 | A | -- | 6.5 | 12 | 150048 |
| 3.4 | 38 | 3.2 | 1.7 | U | -3.3 | 8.5 | .3 | 150053 |
| 2.1 | 52 | 7.0 | 4.2 | A | -5.6 | 6.2 | 7.1 | 150057 |
| 1.7 | -- | 5.5 | 1.3 | U | -- | 5.5 | 4.6 | 150209 |
| 3.5 | 54 | 11 | 4.5 | A | -5.6 | 6.2 | 5.1 | 150244 |
| 2.1 | 40 | 4.6 | .60 | U | -3.8 | 8.0 | .7 | 150246 |
| 4.7 | 62 | 10 | 2.7 | A | -4.3 | 7.5 | 3.4 | 150258 |
| 1.8 | -- | 5.2 | 4.1 | F | -- | 5.0 | 12 | 150365 |
| 3.2 | -- | 10 | 9.5 | U | -- | 5.7 | 12 | 150375 |
| 1.2 | 25 | 4.2 | 1.0 | U | -4.3 | 7.5 | 1.7 | 150424 |
| 2.6 | 66 | 5.4 | .80 | U | -6.2 | 5.6 | 8.5 | 150425 |
| 3.6 | 98 | 13 | 1.0 | U | -- | 6.3 | 6.5 | 150426 |
| 26.0 | -- | 13 | 56 | A | -- | 7.5 | 15 | 150726 |
| 9.1 | -- | 12 | 1.4 | A | -- | 5.7 | 18 | 150729 |
| 31.0 | 260 | 33 | 26 | A | -5.4 | 6.5 | 73.7 | 150730 |

Table 10.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Monmouth County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) | Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | LSI | AI | LI |
| 250029 | 400644 | 740344 | 04/29/82 | 150 | 6.8 | 34 | 21 | 14.2 | 8.5 | 80 | 7.0 | 9.0 | U | -2.1 | 9.7 | 0.6 |
| 250372 | 400802 | 740231 | 08/31/61 | 156 | 5.9 | 6 | 7 | 12.2 | 2.9 | 53 | 9.0 | 4.8 | U | -4.3 | 7.5 | 3.0 |
| 250504 | 400730 | 740757 | 05/05/82 | 47 | 5.1 | 4 | 7 | 15.0 | 2.7 | 45 | 8.0 | 7.0 | F | -5.2 | 6.5 | 4.7 |
| 250505 | 400652 | 740445 | 04/29/82 | 138 | 4.8 | 1 | 2 | 13.0 | .70 | 48 | 8.0 | 8.0 | F | -6.8 | 5.0 | 20 |
| 250510 | 400726 | 740739 | 06/24/82 | 52 | 6.0 | 12 | 17 | 12.0 | 6.7 | 110 | 34 | 13 | F | -3.5 | 8.3 | 5.1 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

Table 11.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Ocean County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 290013 | 395530 | 741220 | 08/25/81 | 99 | 4.3 | 1 | 1 | 14.0 |
| 290017[c] | 394829 | 740535 | 09/21/62 | 397 | 7.4 | 57 | 40 | 16.5 |
| 290020 | 394829 | 740535 | 10/28/77 | 12 | 6.8 | 16 | 25 | -- |
| 290022 | 395422 | 740458 | 08/28/81 | 200 | 6.2 | 10 | 4 | 13.0 |
| 290028 | 400121 | 740602 | 06/22/61 | 213 | 7.1 | 54 | 23 | 12.8 |
| 290052 | 400614 | 740706 | 06/22/61 | 100 | 5.2 | 3 | 3 | 13.5 |
| 290055 | 395607 | 741240 | 08/31/81 | 59 | 4.8 | 1 | 1 | 12.0 |
| 290058 | 395715 | 741231 | 11/07/84 | 56 | 5.6 | 8[b] | 17 | 13.6 |
| 290088 | 395933 | 741312 | 08/31/81 | 86 | 5.0 | 2 | 5 | 13.0 |
| 290094 | 395941 | 741209 | 11/07/84 | 125 | 4.4 | <1[b] | 6 | 12.8 |
| 290097 | 395945 | 741222 | 08/31/81 | 126 | 5.0 | 3 | 7 | 12.5 |
| 290099 | 395956 | 740344 | 08/31/61 | 110 | 7.2 | 30 | 182 | 12.8 |
| 290121 | 400206 | 742110 | 04/13/82 | 74 | 6.0 | 8 | 4 | 13.0 |
| 290122 | 400205 | 741933 | 04/13/82 | 71 | 6.2 | 52 | <1 | 14.5 |
| 290123 | 400212 | 741936 | 04/13/82 | 80 | 5.2 | 2 | 1 | 13.5 |
| 290126 | 400224 | 742137 | 04/13/82 | 45[a] | 5.1 | 4 | <1 | 13.0 |
| 290141 | 400414 | 742702 | 07/10/84 | 71 | 6.6 | 12 | 14 | 16.0 |
| 290155 | 400438 | 742708 | 10/26/84 | 16 | 4.4 | 1[b] | 3 | 15.6 |
| 290156 | 400438 | 742709 | 10/26/84 | 16 | 4.5 | 1[b] | 3 | 15.0 |
| 290230 | 400724 | 742342 | 12/17/81 | 100 | 7.6 | 44 | 37 | 11.0 |
| 290315 | 395317 | 742402 | 04/24/73 | 18 | 4.6 | <1 | 6 | -- |
| 290415 | 395322 | 742305 | 10/25/84 | 43 | 5.2 | 3[b] | 2 | 12.5 |
| 290416 | 395322 | 742306 | 10/25/84 | 21 | 4.9 | 2[b] | 4 | 13.9 |
| 290428 | 400039 | 741930 | 12/07/81 | 36 | 5.0 | 2 | 9 | 13.0 |
| 290432 | 400304 | 740933 | 11/19/81 | 60 | 7.6 | 64 | 67 | 17.0 |
| 290480 | 395324 | 742332 | 10/25/84 | 24 | 4.6 | 1[b] | 2 | 13.5 |
| 290483 | 395646 | 742108 | 03/29/82 | 155 | 4.9 | 2 | 1 | 13.0 |
| 290487 | 395708 | 742130 | 03/29/82 | 92 | 4.9 | 2 | 2 | 12.5 |
| 290488 | 395729 | 742343 | 11/24/81 | 143 | 5.0 | 4 | 1 | 12.0 |
| 290489 | 395718 | 742343 | 11/24/81 | 175 | 5.1 | 3 | 2 | 12.0 |
| 290493 | 395930 | 741617 | 12/07/81 | 101 | 5.1 | 2 | 1 | 12.0 |
| 290494 | 400059 | 741833 | 12/07/81 | 81 | 5.2 | 2 | 2 | 13.0 |
| 290500 | 400227 | 741735 | 03/10/82 | 67 | 5.4 | 4 | 8 | 13.0 |
| 290502 | 400236 | 741723 | 03/10/82 | 117 | 5.3 | 4 | 7 | 14.0 |
| 290508 | 395528 | 740826 | 08/25/81 | 153 | 5.7 | 4 | 4 | 12.5 |
| 290509 | 394613 | 741215 | 06/30 70 | 153 | 4.2 | 1 | 2 | 13.5 |
| 290512 | 394741 | 741122 | 08/25/81 | 160 | 4.6 | 1 | 1 | 13.0 |
| 290513 | 394744 | 741418 | 09/20/84 | 21 | 6.2 | 12 | 3 | 15.3 |
| 290514[c] | 394744 | 741418 | 05/24/83 | 316 | 5.8 | 2 | 5 | 13.0 |
| 290515 | 395558 | 741013 | 08/25/81 | 197 | 4.7 | 1 | 2 | 12.0 |
| 290521 | 400536 | 740252 | 09/01/81 | 134 | 6.6 | 52 | 82 | 13.5 |
| 290523 | 400551 | 740243 | 09/01/81 | 130 | 6.4 | 28 | 147 | 13.5 |
| 290533 | 400501 | 740455 | 09/03/81 | 75 | 6.4 | 40 | 35 | 14.5 |
| 290536 | 395636 | 740439 | 08/31/61 | 174 | 6.7 | 28 | 5 | 13.9 |
| 290538 | 395635 | 740441 | 08/28/81 | 175 | 6.0 | 26 | 33 | 13.0 |
| 290553 | 394009 | 741304 | 08/15/63 | 53[a] | 4.0 | 1 | 10 | 13.5 |
| 290554 | 394021 | 741351 | 12/02/81 | 234 | 5.5 | 2 | 2 | 13.0 |
| 290555 | 394039 | 741551 | 12/15/81 | 140 | 6.3 | 5 | 2 | 14.5 |
| 290566 | 394444 | 741210 | 08/25/81 | 155[a] | 4.4 | 1 | 2 | 12.0 |
| 290569 | 394527 | 741444 | 08/25/81 | 252 | 5.0 | 1 | 1 | 12.0 |
| 290571 | 394554 | 741920 | 12/15/81 | 146 | 6.4 | 5 | 1 | 5.5 |
| 290578[c] | 395530 | 741220 | 08/25/81 | 248 | 5.4 | 2 | 1 | 12.5 |
| 290594 | 394622 | 741229 | 12/15/81 | 150 | 4.8 | 1 | 2 | 13.0 |
| 290596 | 400046 | 741721 | 11/23/81 | 85 | 5.5 | 3 | 1 | 11.0 |
| 290608 | 400019 | 741749 | 12/16/81 | 80 | 5.9 | 6 | 4 | 13.0 |

Footnotes at end of table.

Table 11.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Ocean County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 0.40 | 28 | 5.8 | 7.0 | U | -7.5 | 4.3 | 16 | 290013 |
| 16 | 115 | 7.0 | 12 | F | -1.0 | 10.8 | .4 | 290017[c] |
| 10 | 195 | 57 | 21 | F | -- | 9.4 | 6.4 | 290020 |
| 1.5 | 48 | 4.7 | 7.0 | F | -4.0 | 7.8 | 1.4 | 290022 |
| 9.0 | 110 | 3,6 | 5.5 | U | -1.7 | 10.2 | .2 | 290028 |
| 1.2 | 40 | 5.2 | 5.9 | -- | -5.6 | 6.2 | 4.5 | 290052 |
| .30 | 34 | 6.5 | 5.3 | U | -7.1 | 4.7 | 15 | 290055 |
| 6.8 | 101 | 28 | 16 | U | -4.1 | 7.7 | 7.0 | 290058 |
| 2.0 | 61 | 15 | 3.8 | F | -5.8 | 6.0 | 13 | 290088 |
| 2.4 | 67 | 18 | 16 | U | -6.6 | 5.2 | 42 | 290094 |
| 2.7 | 70 | 17 | 5.7 | U | -5.5 | 6.3 | 10 | 290097 |
| 73 | 668 | 264 | 13 | U | -1.0 | 10.9 | 13 | 290099 |
| 1.4 | 25 | 3.0 | 3.0 | U | -4.3 | 7.4 | .9 | 290121 |
| .18 | 74 | 2.0 | 10 | U | -4.2 | 7.6 | .2 | 290122 |
| .51 | 21 | 3.0 | 1.0 | U | -6.2 | 5.6 | 2.6 | 290123 |
| .19 | 19 | 3.0 | 1.0 | F | -6.4 | 5.4 | 1.3 | 290126 |
| 5.7 | 58 | 2.6 | 13 | F | -2.9 | 8.8 | 1.4 | 290141 |
| 1.3 | 23 | 4.4 | 11 | F | -6.8 | 4.9 | 18 | 290155 |
| 1.3 | 24 | 4.0 | 9.9 | F | -6.8 | 5.0 | 16 | 290156 |
| 14.8 | 69 | 4.0 | 4.0 | F | -1.0 | 10.8 | .2 | 290230 |
| 2.3 | 22 | 2.5 | 12 | F | -- | 5.4 | 16 | 290315 |
| .66 | 17 | 3.1 | 5.1 | F | -5.9 | 5.9 | 3.2 | 290415 |
| 1.4 | 22 | 3.5 | 8.1 | F | -6.0 | 5.7 | 6.7 | 290416 |
| 3.73 | 48 | 12 | 5.0 | U | -5.5 | 6.3 | 11 | 290428 |
| 26.8 | 86 | 3.0 | 6.0 | F | -0.5 | 11.2 | .2 | 290432 |
| .73 | 19 | 3.5 | 8.4 | F | -6.9 | 4.9 | 14 | 290480 |
| .37 | 18 | 4.0 | 1.0 | U | -6.6 | 5.2 | 3.3 | 290483 |
| .78 | 26 | 8.0 | 2.0 | U | -6.3 | 5.5 | 6.7 | 290487 |
| .26 | 17 | 3.0 | <1.0 | F | -6.4 | 5.4 | 1.3 | 290488 |
| .67 | 20 | 3.0 | 3.0 | F | -6.0 | 5.8 | 2.5 | 290489 |
| .49 | 16 | 3.0 | 2.0 | F | -6.3 | 5.5 | 3.2 | 290493 |
| .88 | 27 | 8.0 | 2.0 | F | -5.9 | 5.8 | 6.7 | 290494 |
| 3.29 | 51 | 15 | 3.0 | F | -4.9 | 6.9 | 6.1 | 290500 |
| 2.71 | -- | 8.0 | 8.0 | F | -- | 6.7 | 4.9 | 290502 |
| 1.7 | -- | 5.7 | 7.8 | U | -- | 6.9 | 4.0 | 290508 |
| .90 | 40 | 6.6 | 15 | U | -7.2 | 4.6 | 25 | 290509 |
| .50 | -- | 4.3 | 10 | U | -- | 4.7 | 17 | 290512 |
| 1.0 | 8 | 9.9 | 1.1 | F | -4.1 | 7.7 | 1.3 | 290513 |
| 1.9 | 38 | 3.4 | 13 | F | -5.0 | 6.8 | 9.2 | 290514[c] |
| .80 | -- | 6.8 | 11 | U | -- | 5.0 | 21 | 290515 |
| 33 | 290 | 90 | .7 | U | -1.6 | 10.2 | 2.5 | 290521 |
| 59 | 569 | 280 | 10 | U | -1.9 | 10.0 | 15 | 290523 |
| 14 | 138 | 16 | 13 | U | -2.3 | 9.5 | .9 | 290533 |
| 2.0 | 84 | 4.4 | 8.6 | U | -3.0 | 8.8 | .5 | 290536 |
| 13 | 296 | 140 | 20 | U | -2.9 | 8.9 | 8.4 | 290538 |
| 4.0 | 80 | 28 | 6.8 | U | -6.8 | 5.0 | 47 | 290553 |
| .94 | 56 | 3.0 | 6.0 | U | -5.6 | 6.2 | 5.2 | 290554 |
| .70 | -- | 5.0 | 2.0 | F | -- | 7.2 | 1.8 | 290555 |
| .60 | 35 | 5.5 | 7.8 | F | -7.2 | 4.6 | 16 | 290566 |
| .40 | 33 | 4.7 | 4.0 | F | -6.8 | 5.0 | 11 | 290569 |
| .35 | 17 | 5.0 | <1.0 | F | -4.9 | 7.0 | 1.6 | 290571 |
| .40 | -- | 5.8 | 6.0 | U | -- | 5.9 | 7.2 | 290578[c] |
| .59 | 37 | 6.0 | 8.0 | F | -6.8 | 5.0 | 17 | 290594 |
| .44 | 16 | 5.0 | <1.0 | F | -5.8 | 6.0 | 2.7 | 290596 |
| 1.39 | 27 | 6.0 | 2.0 | F | -4.6 | 7.2 | 1.8 | 290608 |

Table 11.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Ocean County, New Jersey--Continued

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 290611 | 400051 | 741657 | 11/23/81 | 77 | 5.4 | 4 | 5 | 12.0 |
| 290612 | 395454 | 740906 | 12/28/81 | 90 | 4.3 | 1 | 3 | 14.5 |
| 290613 | 395248 | 741011 | 12/28/81 | 200 | 5.3 | 2 | 4 | 13.0 |
| 290617 | 395652 | 740442 | 08/28/81 | 175 | 4.7 | 10 | 5 | 13.0 |
| 290620 | 395323 | 742255 | 08/04/61 | 18 | 5.8 | 2 | 2 | -- |
| 290622 | 400149 | 742631 | 10/26/71 | 99 | 5.1 | 1 | 3 | -- |
| 290629 | 400342 | 740825 | 01/05/82 | 60 | 5.0 | 4 | 1 | 13.5 |
| 290631 | 395418 | 741402 | 12/28/81 | 90 | 5.8 | 8 | 1 | 14.0 |
| 290633 | 400105 | 741152 | 01/07/82 | 77 | 5.6 | 4 | 18 | 17.0 |
| 290637 | 395734 | 742241 | 01/20/82 | 116 | 5.6 | 4 | 1 | 15.0 |
| 290638 | 394629 | 741441 | 01/21/82 | 108 | 5.3 | 4 | 1 | 11.0 |
| 290639 | 393647 | 741923 | 02/16/82 | 80 | 5.5 | 4 | 1 | 11.0 |
| 290640 | 393653 | 741945 | 02/16/82 | 215 | 6.7 | 16 | 2 | 9.0 |
| 290642 | 394656 | 742240 | 02/16/82 | 205 | 5.5 | 2 | 1 | 12.0 |
| 290644 | 394242 | 741713 | 02/17/82 | 78 | 5.8 | 4 | 2 | 11.0 |
| 290645 | 400134 | 741029 | 05/13/82 | 35 | 5.5 | 8 | 8 | 13.5 |
| 290646 | 395054 | 741101 | 02/22/82 | 75 | 5.6 | 4 | 8 | 9.5 |
| 290648 | 400459 | 741535 | 05/20/82 | 80 | 5.0 | 2 | 2 | 14.0 |
| 290650 | 393955 | 741657 | 02/10/82 | 46 | 5.5 | 4 | 2 | 11.0 |
| 290651 | 395656 | 740656 | 03/31/82 | 69 | 6.0 | 14 | 5 | 14.0 |
| 290652 | 394153 | 741505 | 02/22/82 | 100 | 5.4 | 2 | 2 | 12.0 |
| 290653 | 394053 | 741422 | 03/17/82 | 70 | 7.0 | 54 | 12 | 12.0 |
| 290655 | 394600 | 741256 | 03/17/82 | 50 | 5.3 | 4 | 2 | 15.0 |
| 290656 | 395026 | 741102 | 03/15/82 | 206 | 5.5 | 4 | 4 | 12.0 |
| 290659 | 400121 | 741612 | 03/30/82 | 64 | 5.6 | 6 | 12 | 12.0 |
| 290661 | 394453 | 741434 | 05/11/82 | 91 | 5.3 | 4 | 1 | 12.0 |
| 290662 | 395332 | 741157 | 12/21/81 | 67 | 6.1 | 10 | <1 | 8.0 |
| 290663 | 400352 | 740813 | 05/03/82 | 38 | 5.0 | 2 | 4 | 14.5 |
| 290665 | 395729 | 740730 | 05/18/82 | 55 | 5.3 | 6 | 4 | 13.5 |
| 290666 | 400004 | 741206 | 05/10/82 | 88 | 4.6 | 1 | 6 | 14.0 |
| 290668 | 400557 | 741859 | 05/26/82 | 62 | 5.4 | 4 | 22 | 13.5 |
| 290669 | 400709 | 741522 | 05/26/82 | 60 | 5.0 | 4 | 2 | 15.5 |
| 290670 | 400603 | 741819 | 05/20/82 | 26 | 5.0 | 1 | 8 | 13.0 |
| 290671 | 395049 | 741110 | 05/11/82 | 53 | 5.2 | 4 | 3 | 13.5 |
| 290672 | 395158 | 741052 | 05/12/82 | 50 | 4.8 | 2 | 2 | 11.5 |
| 290673 | 400622 | 741307 | 05/25/82 | 28 | 5.3 | 1 | 22 | 15.0 |
| 290674 | 393805 | 741853 | 05/17/82 | 65 | 4.9 | 2 | <1 | 14.0 |
| 290676 | 400113 | 741601 | 05/26/82 | 63 | 5.5 | 4 | 1 | 13.0 |
| 290677 | 395736 | 742125 | 05/26/82 | 89 | 4.2 | 1 | 1 | 14.0 |
| 290678 | 400444 | 740421 | 05/25/82 | 80 | 5.4 | 6 | 5 | 14.0 |
| 290679 | 400500 | 740345 | 05/25/82 | 90 | 6.9 | 24 | 9 | 13.5 |
| 290680 | 400413 | 742805 | 05/20/82 | 66 | 5.0 | 2 | 21 | 14.0 |
| 290681 | 394802 | 741045 | 05/10/82 | 100 | 4.4 | 1 | 1 | 14.5 |
| 290682 | 394115 | 741505 | 05/05/82 | 78 | 6.0 | 20 | 15 | 13.5 |
| 290683 | 394134 | 741418 | 05/04/82 | 53 | 7.3 | 46 | 18 | 14.5 |
| 290684 | 393608 | 742100 | 05/17/82 | 90 | 5.1 | 4 | 1 | 14.0 |
| 290685 | 395326 | 740956 | 05/18/82 | 177 | 4.6 | 1 | 2 | 13.5 |
| 290686 | 400259 | 740718 | 05/12/82 | 184 | 7.0 | 44 | 14 | 13.5 |
| 290688 | 400415 | 740539 | 05/03/82 | 38 | 5.0 | 2 | 6 | 14.5 |
| 290689 | 400549 | 740516 | 04/21/82 | 131 | 6.8 | 20 | 5 | 14.5 |
| 290691 | 395756 | 740834 | 04/28/82 | 108 | 4.7 | 2 | 5 | 12.5 |
| 290692 | 400102 | 740901 | 05/05/82 | 123 | 5.0 | 4 | 4 | 14.5 |
| 290694 | 395712 | 740804 | 05/03/82 | 58 | 5.3 | 4 | <1 | 15.5 |
| 290695 | 400219 | 741436 | 04/27/82 | 76 | 5.2 | 4 | <1 | 12.5 |
| 290696 | 400455 | 741603 | 05/04/82 | 62 | 5.5 | 8 | 1 | 13.0 |
| 290701 | 395003 | 741134 | 05/12/82 | 147 | 4.4 | 1 | 1 | 12.5 |
| 290702 | 395046 | 741147 | 04/22/82 | 75 | 5.5 | 4 | 1 | 14.4 |
| 290703 | 395050 | 740519 | 05/20/82 | 291 | 6.6 | 4 | 1 | 16.0 |
| 290704 | 400044 | 741859 | 04/27/82 | 25 | 5.1 | 4 | 19 | 14.5 |
| 290705 | 400511 | 741029 | 04/27/82 | 110 | 6.3 | 16 | 8 | 12.5 |
| 290706 | 395615 | 742059 | 05/04/82 | 94 | 5.3 | 4 | 1 | 12.0 |
| 290707 | 395754 | 742202 | 04/21/82 | 95 | 5.0 | 4 | 1 | 12.0 |
| 290708 | 400107 | 741821 | 04/27/82 | 60 | 5.5 | 4 | 4 | 13.5 |
| 290709 | 395401 | 741006 | 04/27/82 | 76 | 5.6 | 6 | 2 | 14.0 |
| 290710 | 395528 | 741600 | 03/10/82 | 100 | 5.5 | 4 | 1 | 12.5 |

Footnotes at end of table.

Table 11.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Ocean County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 1.98 | 26 | 7.0 | <1.0 | F | -5.1 | 6.7 | 2.7 | 290611 |
| 1.2 | 54 | 8.8 | 15 | U | -7.0 | 4.8 | 28 | 290612 |
| 1.54 | 25 | 5.0 | 8.0 | F | -5.6 | 6.2 | 7.7 | 290613 |
| 1.8 | 69 | 18 | 8.3 | U | -5.5 | 6.4 | 3.4 | 290617 |
| .80 | 19 | 3.6 | 4.6 | F | -- | 6.4 | 4.9 | 290620 |
| 1.2 | 18 | 5.4 | 4.4 | F | -- | 5.6 | 12 | 290622 |
| .54 | 37 | 6.0 | 2.0 | U | -6.1 | 5.7 | 2.6 | 290629 |
| .27 | 19 | 1.1 | 1.3 | F | -5.2 | 6.5 | .4 | 290631 |
| 7.0 | 100 | 12 | 8.0 | A | -4.3 | 7.4 | 6.3 | 290633 |
| .44 | 26 | 5.0 | 1.0 | F | -5.5 | 6.2 | 2.0 | 290637 |
| .51 | 31 | 5.0 | 8.0 | F | -5.8 | 6.0 | 3.9 | 290638 |
| .32 | -- | 7.0 | <1.0 | F | -- | 6.0 | 2.7 | 290639 |
| .79 | -- | 4.0 | 12 | F | -- | 8.2 | 1.1 | 290640 |
| .36 | -- | 3.0 | .5 | F | -- | 5.8 | 2.6 | 290642 |
| .64 | 17 | 5.0 | 1.0 | F | -5.2 | 6.6 | 2.0 | 290644 |
| 3.13 | 58 | 15 | 7.0 | U | -4.5 | 7.3 | 3.6 | 290645 |
| 3.28 | 41 | 8.0 | 14 | U | -4.7 | 7.1 | 6.5 | 290646 |
| .73 | 49 | 16 | 2.0 | F | -6.2 | 5.6 | 12 | 290648 |
| .94 | 44 | 6.0 | 10 | F | -5.4 | 6.5 | 4.7 | 290650 |
| 1.83 | 41 | 8.0 | 2.0 | U | -4.0 | 7.8 | 1.0 | 290651 |
| .59 | 26 | 6.0 | 3.0 | U | -5.9 | 5.9 | 5.8 | 290652 |
| 4.7 | 100 | 12 | 8.0 | U | -2.0 | 9.8 | .5 | 290653 |
| .62 | 31 | 7.0 | 5.0 | F | -5.7 | 6.1 | 3.8 | 290655 |
| 1.4 | 36 | 4.0 | 10 | U | -5.2 | 6.6 | 4.0 | 290656 |
| 4.82 | 83 | 26 | 9.0 | F | -4.4 | 7.5 | 7.7 | 290659 |
| .35 | 43 | 16 | 2.0 | F | -6.0 | 5.8 | 6.2 | 290661 |
| .18 | 32 | 8.0 | 2.0 | F | -5.1 | 6.8 | 1.3 | 290662 |
| 1.45 | 30 | 4.0 | 4.0 | U | -5.9 | 5.9 | 4.9 | 290663 |
| 1.63 | 43 | 16 | <1.0 | U | -5.1 | 6.7 | 3.9 | 290665 |
| 2.5 | 61 | 11 | 10 | A | -6.4 | 5.4 | 26 | 290666 |
| 8.67 | -- | 4.0 | <1.0 | F | -- | 7.3 | 1.7 | 290668 |
| .70 | 63 | 12 | <1.0 | U | -5.9 | 5.8 | 4.5 | 290669 |
| 3.29 | -- | 12 | 14 | F | -- | 5.9 | 32 | 290670 |
| 1.28 | 38 | 7.0 | 6.0 | U | -5.5 | 6.3 | 4.0 | 290671 |
| .73 | 42 | 8.0 | 8.0 | F | -6.5 | 5.4 | 9.8 | 290672 |
| 8.67 | 101 | 22 | 21 | U | -5.2 | 6.6 | 53 | 290673 |
| .13 | 35 | 7.0 | <1.0 | U | -7.1 | 4.7 | 5.5 | 290674 |
| .19 | -- | 4.0 | <1.0 | F | -- | 5.8 | 1.7 | 290676 |
| .20 | 89 | 2.0 | 2.0 | U | -7.9 | 3.9 | 4.9 | 290677 |
| 2.06 | -- | 20 | <1.0 | U | -- | 6.9 | 4.9 | 290678 |
| 3.72 | 48 | 9.0 | <0.1 | U | -2.5 | 9.2 | .5 | 290679 |
| 8.35 | 87 | 7.0 | 14 | F | -5.2 | 6.6 | 12 | 290680 |
| .58 | 48 | 5.0 | 10 | F | -7.2 | 4.6 | 18 | 290681 |
| 6.08 | 89 | 15 | 22 | F | -3.3 | 8.5 | 2.2 | 290682 |
| 7.02 | 82 | 7.0 | 9.0 | F | -1.6 | 10.2 | .4 | 290683 |
| .36 | 13 | 4.0 | 2.0 | U | -6.1 | 5.7 | 1.9 | 290684 |
| .82 | 34 | 5.0 | 8.0 | F | -6.9 | 4.9 | 15 | 290685 |
| 5.69 | 87 | 2.0 | 5.0 | U | -2.0 | 9.8 | .2 | 290686 |
| 2.45 | 89 | 14 | 9.0 | U | -5.7 | 6.1 | 14 | 290688 |
| 1.92 | 55 | 4.0 | 6.0 | U | -3.0 | 8.8 | .6 | 290689 |
| 1.98 | 77 | 20 | <1.0 | U | -6.1 | 5.7 | 15 | 290691 |
| 1.71 | 67 | 16 | 2.0 | U | -5.6 | 6.2 | 6.2 | 290692 |
| .01 | 51 | 15 | <1.0 | U | -7.5 | 4.3 | 5.5 | 290694 |
| .10 | 14 | 4.0 | 2.0 | F | -6.6 | 5.2 | 1.9 | 290695 |
| .42 | 42 | 14 | <1.0 | F | -5.4 | 6.4 | 2.6 | 290696 |
| .35 | 31 | 3.0 | 8.0 | U | -7.5 | 4.3 | 13 | 290701 |
| .26 | 25 | 8.0 | 1.0 | U | -5.8 | 5.9 | 3.1 | 290702 |
| .45 | 32 | 2.0 | 7.0 | U | -4.5 | 7.3 | 2.5 | 290703 |
| 7.62 | 90 | 23 | 16 | F | -4.8 | 7.0 | 12 | 290704 |
| 3.33 | 59 | 4.0 | 2.0 | F | -3.4 | 8.4 | .5 | 290705 |
| .31 | 18 | 3.0 | 1.0 | F | -6.0 | 5.8 | 1.3 | 290706 |
| .36 | 18 | 4.0 | 1.0 | F | -6.2 | 5.6 | 1.7 | 290707 |
| 1.46 | -- | 10 | 18 | F | -- | 6.7 | 8.2 | 290708 |
| .60 | 33 | 8.0 | 8.0 | F | -5.2 | 6.6 | 3.3 | 290709 |
| .39 | 10 | 3.0 | 2.0 | F | -5.7 | 6.1 | 1.6 | 290710 |

Table 11.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Ocean County, New Jersey--continued

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 290711 | 400204 | 741507 | 04/19/82 | 53 | 5.7 | 8 | 2 | 12.0 |
| 290712 | 400241 | 741319 | 01/20/82 | 89 | 5.3 | 2 | 1 | 11.0 |
| 290716 | 395134 | 741132 | 03/31/82 | 140 | 5.3 | 4 | 1 | 12.0 |
| 290717 | 400457 | 740926 | 03/22/82 | 101 | 6.7 | 18 | 9 | 13.0 |
| 290718 | 395550 | 740723 | 05/12/82 | 79 | 7.6 | 36 | 20 | 14.0 |
| 290719 | 400228 | 742756 | 05/26/82 | 125 | 5.0 | 1 | 1 | 13.0 |
| 290721 | 395705 | 742227 | 03/29/82 | 168 | 4.6 | 2 | 1 | 12.0 |
| 290722 | 400102 | 741048 | 04/26/82 | 65 | 4.8 | 4 | 6 | 13.0 |
| 290724 | 395204 | 741154 | 03/31/82 | 150 | 4.5 | 1 | 1 | 12.0 |
| 290725 | 400107 | 741825 | 04/27/82 | 49 | 5.1 | 2 | 2 | 14.5 |
| 290726 | 400432 | 740831 | 11/12/81 | 67 | 5.5 | 2 | 25 | 12.0 |
| 290727 | 395832 | 741549 | 05/27/82 | 60 | 4.9 | 1 | 1 | 14.0 |
| 290728 | 400142 | 740631 | 05/24/82 | 96 | 5.2 | 4 | 3 | 13.0 |
| 290729 | 400215 | 741448 | 06/22/82 | 78 | 6.4 | 8 | 1 | 10.5 |
| 290730 | 394000 | 741904 | 06/24/82 | 65 | 6.0[a] | 4[b] | 1 | 15.0 |
| 290731 | 394823 | 741358 | 09/27/84 | 64 | 4.3 | <1[b] | 1 | 14.0 |
| 290732 | 395230 | 741253 | 01/21/82 | 91 | 5.3 | 2 | 2 | 11.0 |
| 290733 | 400426 | 742042 | 06/29/82 | 57 | 6.0 | 24 | <1 | 14.0 |
| 290735 | 395745 | 742124 | 03/29/82 | 173 | 6.2 | 12 | 15 | 11.0 |
| 290737 | 394424 | 741403 | 05/11/82 | 48 | 5.3 | 4 | 1 | 12.5 |
| 290738 | 395325 | 741217 | 12/21/81 | 100 | 6.0 | 12 | 25 | 13.5 |
| 290742 | 400009 | 741405 | 05/24/82 | 48 | 6.0 | 1 | 4 | 14.0 |
| 290743 | 394728 | 741202 | 04/28/82 | 60 | 6.1 | 12 | 6 | 15.0 |
| 290746 | 400426 | 741453 | 05/19/82 | 120 | 5.3 | 3 | 2 | 13.5 |
| 290747 | 395430 | 741049 | 02/23/82 | 117 | 4.4 | 1 | 2 | 11.5 |
| 290749 | 400124 | 741049 | 05/13/82 | 69 | 5.5 | 4 | 3 | 13.5 |
| 290750 | 400229 | 741441 | 05/19/82 | 54 | 5.8 | 1 | <1 | 13.0 |
| 290752 | 400535 | 740823 | 05/27/82 | 60 | 4.9 | 1 | 12 | 13.5 |
| 290753 | 400710 | 741714 | 04/28/82 | 40 | 5.6 | 6 | 1 | 13.0 |
| 290754 | 400525 | 740807 | 05/27/82 | 55 | 4.7 | 1 | 24 | 14.0 |
| 290756 | 395048 | 740519 | 05/13/82 | 331 | 6.3 | 18 | 3 | 14.0 |
| 290757 | 400137 | 741602 | 11/23/81 | 82 | 5.5 | 3 | <1 | 11.0 |
| 290759 | 400126 | 741603 | 05/05/82 | 60 | 5.4 | 4 | <1 | 12.5 |
| 290760 | 400106 | 741400 | 05/19/82 | 59 | 5.7 | 1 | 4 | 14.5 |
| 290761 | 395809 | 740706 | 05/19/82 | 70 | 5.4 | 1 | 1 | 15.0 |
| 290762 | 400022 | 741405 | 12/14/81 | 60 | 6.3 | 20 | 22 | 14.1 |
| 290763 | 393827 | 741830 | 03/03/82 | 148 | 5.3 | 4 | 1 | 12.0 |
| 290764 | 400356 | 740417 | 03/03/82 | 107 | 6.8 | 4 | 5 | 13.0 |
| 290765 | 394456 | 741819 | 12/02/81 | 257 | 5.7 | 2 | 1 | 11.5 |
| 290767 | 400416 | 740718 | 05/10/82 | 62 | 5.0 | 4 | 1 | 14.0 |
| 290768 | 394205 | 741657 | 05/06/82 | 154 | 5.7 | 4 | 1 | 12.0 |
| 290769 | 395554 | 741735 | 05/10/82 | 80 | 5.3 | 4 | 1 | 13.5 |
| 290772 | 395451 | 742702 | 09/11/84 | 42 | 4.5 | 2[b] | 1 | 13.0 |
| 290773 | 393855 | 742008 | 06/02/83 | 37 | 5.6 | 7 | 2 | 12.5 |
| 290789 | 394949 | 742029 | 06/14/84 | 69 | 5.3 | 3 | <1 | 12.5 |
| 290790 | 395107 | 742255 | 06/14/84 | 51 | 5.2 | 3 | 2 | 14.5 |
| 290791 | 394111 | 742141 | 09/11/84 | 65 | 4.8 | 1 | 1 | 13.0 |
| 290915 | 395015 | 741240 | 10/18/84 | 145 | 4.6 | 1[b] | <1 | 12.7 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

a Number is depth of well. Depth to bottom of screen not reported.

b Field value not reported; laboratory value used.

c Well is deeper of pair of nested piezometers, and is not plotted on pl. 1.

Table 11.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Ocean County, New Jersey--Continued

| Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | | Well number |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSI | AI | LI | |
| 0.71 | 34 | 5.0 | 1.0 | F | -5.0 | 6.9 | 1.0 | 290711 |
| .32 | 77 | 34 | 1.0 | F | -6.3 | 5.5 | 25 | 290712 |
| .42 | 25 | 6.0 | 2.0 | F | -5.9 | 5.9 | 2.6 | 290716 |
| 3.39 | 49 | 5.0 | 8.0 | F | -2.9 | 8.9 | .9 | 290717 |
| 7.82 | 68 | 6.0 | 3.0 | F | -1.4 | 10.4 | .3 | 290718 |
| .21 | -- | 2.0 | 1.0 | F | -- | 4.7 | 3.9 | 290719 |
| .28 | 13 | 3.0 | 2.0 | F | -7.0 | 4.7 | 3.2 | 290721 |
| 2.2 | 60 | 13 | <1.0 | F | -5.7 | 6.1 | 4.9 | 290722 |
| .30 | 31 | 4.0 | 9.0 | F | -7.4 | 4.4 | 15 | 290724 |
| .94 | 19 | 6.0 | 4.0 | F | -6.0 | 5.8 | 6.3 | 290725 |
| 9.82 | 542 | 300 | 16 | U | -4.7 | 7.2 | 220 | 290726 |
| .46 | 53 | 5.0 | 1.0 | F | -6.8 | 5.0 | 8.1 | 290727 |
| 1.51 | 89 | 11 | 2.0 | U | -5.4 | 6.4 | 4.4 | 290728 |
| .20 | 20 | 4.2 | <1.0 | F | -4.8 | 7.0 | .9 | 290729 |
| .25 | 22 | 5.6 | 3.0 | F | -5.4 | 6.4 | 2.8 | 290730 |
| .54 | 28 | 4.2 | 12 | F | -7.3 | 4.4 | 18 | 290731 |
| .65 | 19 | 5.0 | 1.0 | F | -6.0 | 5.8 | 4.1 | 290732 |
| .06 | 18 | 2.9 | 1.0 | F | -5.2 | 6.6 | .2 | 290733 |
| 5.8 | 42 | 6.0 | 5.0 | F | -3.4 | 8.4 | 1.1 | 290735 |
| .36 | 46 | 12 | 2.0 | F | -6.0 | 5.9 | 4.8 | 290737 |
| 9.8 | 130 | 12 | 1.0 | F | -3.4 | 8.5 | 1.5 | 290738 |
| 1.55 | 60 | 2.0 | 8.0 | F | -5.2 | 6.6 | 11 | 290742 |
| 2.34 | 47 | 8.0 | 2.0 | F | -3.8 | 7.9 | 1.1 | 290743 |
| .61 | 24 | 5.0 | 2.0 | F | -5.8 | 6.0 | 3.0 | 290746 |
| .97 | -- | 6.0 | 10 | F | -- | 4.8 | 19 | 290747 |
| 1.20 | 37 | 12 | 2.0 | U | -5.2 | 6.6 | 4.8 | 290749 |
| .18 | 12 | 4.0 | 2.0 | F | -6.3 | 5.5 | 7.7 | 290750 |
| 4.7 | 48 | 55 | 10 | U | -5.9 | 6.0 | 88 | 290752 |
| .34 | 15 | 4.0 | 2.0 | F | -5.5 | 6.3 | 1.3 | 290753 |
| 9.4 | 54 | 11 | 30 | U | -5.7 | 6.1 | 47 | 290754 |
| 1.21 | 65 | 3.0 | 10 | F | -3.8 | 8.0 | .8 | 290756 |
| .07 | 12 | 3.0 | <1.0 | F | -6.6 | 5.2 | 1.8 | 290757 |
| .06 | -- | 4.0 | .5 | F | -- | 5.2 | 1.7 | 290759 |
| 1.50 | 60 | 10 | <1.0 | F | -5.5 | 6.3 | 15 | 290760 |
| .30 | -- | 8.0 | <1.0 | F | -- | 5.3 | 12 | 290761 |
| 8.7 | 90 | 6.0 | 22 | F | -2.9 | 8.9 | 1.6 | 290762 |
| .52 | 31 | 4.0 | 2.0 | U | -5.8 | 6.0 | 1.9 | 290763 |
| 1.97 | 61 | 13 | 2.0 | U | -3.7 | 8.1 | 5.1 | 290764 |
| .30 | 20 | 4.0 | <1.0 | F | -5.9 | 5.9 | 3.3 | 290765 |
| .53 | 60 | 11 | 16 | U | -6.1 | 5.7 | 8.0 | 290767 |
| .45 | 19 | 4.0 | 2.0 | F | -5.4 | 6.4 | 1.9 | 290768 |
| .23 | 20 | 3.0 | 1.0 | F | -6.1 | 5.7 | 1.3 | 290769 |
| .33 | 16 | 4.4 | 2.1 | F | -7.1 | 4.7 | 4.2 | 290772 |
| .98 | 31 | 6.6 | 1.2 | F | -5.0 | 6.8 | 1.6 | 290773 |
| .13 | 21 | 3.8 | .5 | F | -6.5 | 5.3 | 2.0 | 290789 |
| .92 | 24 | 4.7 | 2.1 | F | -5.7 | 6.0 | 2.9 | 290790 |
| .41 | 18 | 4.5 | 2.2 | F | -7.0 | 4.8 | 8.6 | 290791 |
| .17 | 10 | 5.2 | 2.6 | U | -7.5 | 4.2 | 10 | 290915 |

Table 12.--Selected well records, chemical analyses, land use*, and corrosion indices of water from wells in Salem County, New Jersey

[Calculated calcium hardness values are rounded to the nearest whole number; values of 0.4 or less are shown as <1. LSI, Langelier Saturation Index; AI, Aggressive Index; LI, Larson Index; --, no data for a given characteristic; ft, feet; LSD, land surface datum; mg/L, milligrams per liter; °C, degrees Celsius; <, less than; A, agricultural; U, urban (includes residential and areas adjacent to major roadways); F, undeveloped, mostly forested (includes low-density residential and marshland); well locations are shown on pl. 1.]

| Well number | Latitude | Longitude | Date of sample | Depth of screen bottom (ft) | pH (standard units) | Alkalinity (mg/L $CaCO_3$) | Calcium hardness (mg/L $CaCO_3$) | Temperature (°C) | Calcium (mg/L) | Dissolved solids (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Predominant land use | Corrosion Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | LSI | AI | LI |
| 330023 | 393534 | 751020 | 03/15/51 | 62 | 4.7[a] | 1[a] | 14 | -- | 5.6 | 105 | 13 | 5.5 | -- | -- | 5.8 | 24 |
| 330229 | 393321 | 750806 | 06/29/87 | 56 | 4.6 | 1 | 21 | 13.5 | 8.4 | 117 | 14 | 3.0 | A | -5.9 | 5.9 | 23 |
| 330231 | 393319 | 750812 | 12/10/59 | 53 | 5.2[a] | 2 | 1 | 12.5 | .4 | 18 | 3.4 | 3.7 | A | -6.3 | 5.5 | 4.3 |
| 330262 | 393420 | 751345 | 07/22/87 | 93 | 5.1 | 4 | 65 | 12.5 | 26 | 249 | 28 | 70 | A | -4.3 | 7.5 | 28 |
| 330270 | 393445 | 751423 | 07/21/87 | 88 | 5.3 | 12 | 62 | 14.5 | 25 | 229 | 39 | 33 | A | -3.7 | 8.2 | 7.5 |
| 330295 | 393830 | 751226 | 07/29/87 | 84 | 4.9 | 2 | 55 | 13.5 | 22 | 188 | 19 | 22 | A | -4.9 | 6.9 | 25 |
| 330462 | 393449 | 750528 | 12/15/86 | 70 | 4.5 | <1[a] | 2 | 13.0 | .7 | -- | 2.2 | 10 | F | -- | 4.7 | 14 |
| 330463 | 393047 | 750542 | 12/17/86 | 74 | 4.4 | <1[a] | 62 | 13.0 | 25 | -- | 21 | 1.2 | A | -- | 6.2 | 31 |
| 330464 | 393203 | 751705 | 12/16/86 | 58 | 4.8 | 5 | 23 | 13.0 | 9.0 | -- | 23 | 3.8 | A | -- | 6.9 | 7.3 |
| 330465 | 393236 | 751021 | 12/17/86 | 104 | 6.3 | 45 | 28 | 14.0 | 11 | -- | 13 | 2.4 | A | -- | 9.4 | .5 |
| 330466 | 393509 | 751601 | 12/16/86 | 65 | 5.1 | 7 | 67 | 13.0 | 27 | -- | 38 | 34 | A | -- | 7.8 | 13 |
| 330469 | 393057 | 750839 | 09/01/87 | 114 | 7.6 | 87 | 83 | 13.5 | 33 | 130 | 1.6 | 14 | F | -.4 | 11.5 | .2 |

* Land use determined from GIRAS land use of 1972; for wells sampled prior to 1972, U.S. Geological Survey 7.5 minute series topographic maps and well records used for confirmation.

a Field value not reported; laboratory value used.

## APPENDIX A

### Calculations for Four Corrosion Indices

Calculation of the corrosion indices used in this report involves conversion of various constituent concentrations in milligrams per liter to milligrams per liter as equivalent calcium carbonate. The Langelier Saturation Index requires the calculation of a temperature and a salinity correction; the Riddick Corrosion index requires the determination of saturated dissolved oxygen and a calculation of dissolved carbon dioxide.

#### Langelier Saturation Index

$$LSI = pH - pH_s,$$

where $pH_s = A + B - \log (Ca^{2+}) - \log$ total alkalinity, and $Ca^{2+}$ and total alkalinity are expressed as milligrams per liter of equivalent calcium carbonate.

Values for factor A are given below at several temperatures (T), as calculated by Schock and Neff (1982) from equations of Plummer and Busenberg (1982).

| $T^oC$ | A |
|---|---|
| 0 | 2.25 |
| 4 | 2.18 |
| 8 | 2.11 |
| 12 | 2.05 |
| 16 | 1.98 |
| 20 | 1.92 |
| 25 | 1.85 |
| 30 | 1.78 |
| 40 | 1.64 |
| 50 | 1.51 |
| 60 | 1.39 |
| 70 | 1.26 |
| 80 | 1.14 |

For the calculation of $pH_s$, factor A was calculated at any temperature by the following equation--

$$A = 2.24961 - .017853 \times T + .00008238 \times T^2 - .00000041 \times T^3.$$

Factor B is calculated by the following equation from Larson and Buswell (1942). According to Schock and Neff (1982), factor B has not been recalculated.

$$B = 9.7 + [(2.5 \times \sqrt{\mu})/(1.0 + 5.3 \times \sqrt{\mu} + 5.5\mu)],$$

where the value of $\mu$ is .000025 x concentration of dissolved solids.

Larson and Buswell use the constant 9.3 rather than 9.7. Larson (1951, p. 660) shows this term with a value of 9.7, however, the values published in

the Federal Register, Wednesday, August 27, 1980 indicate that, at a dissolved solids concentration of zero, the value for B should be 9.7. Using the constant 9.7 give values generally within a few hundredths of the values listed in the Federal Register, which are given below.

| Total Filtrable Residue (mg/L) | B |
|---|---|
| 0 | 9.70 |
| 100 | 9.77 |
| 200 | 9.83 |
| 400 | 9.86 |
| 800 | 9.89 |
| 1,000 | 9.90 |

The concentration of calcium expressed as equivalent calcium carbonate ($CaCO_3$) is calculated by--

Calcium as $CaCO_3$ = Calcium concentration (mg/L) x 2.497
(Hem, 1985, p. 55).

Alkalinity typically is reported as mg/L of equivalent calcium carbonate.

Aggressive Index

$$AI = pH + \log_{10}(\text{alkalinity} \times \text{calcium hardness}),$$

where calcium hardness is ($Ca^{2+}$) expressed as equivalent $CaCO_3$. The calculation is the same as for calcium in the LSI, above.

Larson Index

$$LI = (\text{Chloride} + \text{sulfate})/\text{alkalinity},$$

where all three constituents are expressed in milligrams per liter of equivalent $CaCO_3$. Chloride concentration is converted by--

Chloride as $CaCO_3$ = Chloride(mg/L) x 1.4117;

sulfate is converted by--

Sulfate as $CaCO_3$ = Sulfate (mg/L) x 1.0421.

Riddick Corrosion Index

RCI = (75/Alkalinity) x [Carbon dioxide + .5 x (Hardness - Alkalinity) + Chloride + 2Nitrate] x (10/Silica) x [(Dissolved oxygen + 2)/Saturated dissolved oxygen],

where carbon dioxide ($CO_2$) is in mg/L (calculated), dissolved oxygen, chloride, silica ($SiO_2$), and nitrate ion also are in mg/L. Alkalinity and hardness are expressed as mg/L of equivalent $CaCO_3$. Saturated dissolved oxygen is calculated.

$CO_2$ is calculated by--

$$CO_2 = 1.60 \times 10^{(6.0 - pH)} \times \text{bicarbonate}$$

(Fishman and Friedman, 1989, p. 147),

where $CO_2$ and bicarbonate are in mg/L. Bicarbonate can be calculated from the total alkalinity concentration in mg/L (making the assumption that all alkalinity is derived from dissolved carbon dioxide species) by dividing by .8202 (see Hem, 1985, p. 55 and 106).

Saturated dissolved oxygen values are calculated in the following manner (R.J. Pickering, U.S.Geological Survey, 1981, written commun.).

Dissolved oxygen (DO) solubility is calculated in milliliters per liter (ml/L)--

$$\ln \text{DO solubility (ml/L)} = -173.4292 + (249.6339 \times 100/T) + (143.3483 \times \ln(T/100)) - (21.8492 \times T/100) + S\,[-0.033096 + (0.014259 \times T/100) - 0.001700 \times (T/100)^2],$$

where S is salinity in grams per kilogram, and temperature (T) is in degrees Kelvin, which is calculated ($273.15 + T\ ^{o}C$).

Salinity (in grams per kilogram) is calculated by the equation--

$$S = 5.572 \times 10^{-4}(SC) + 2.02 \times 10^{-9}(SC)^2,$$

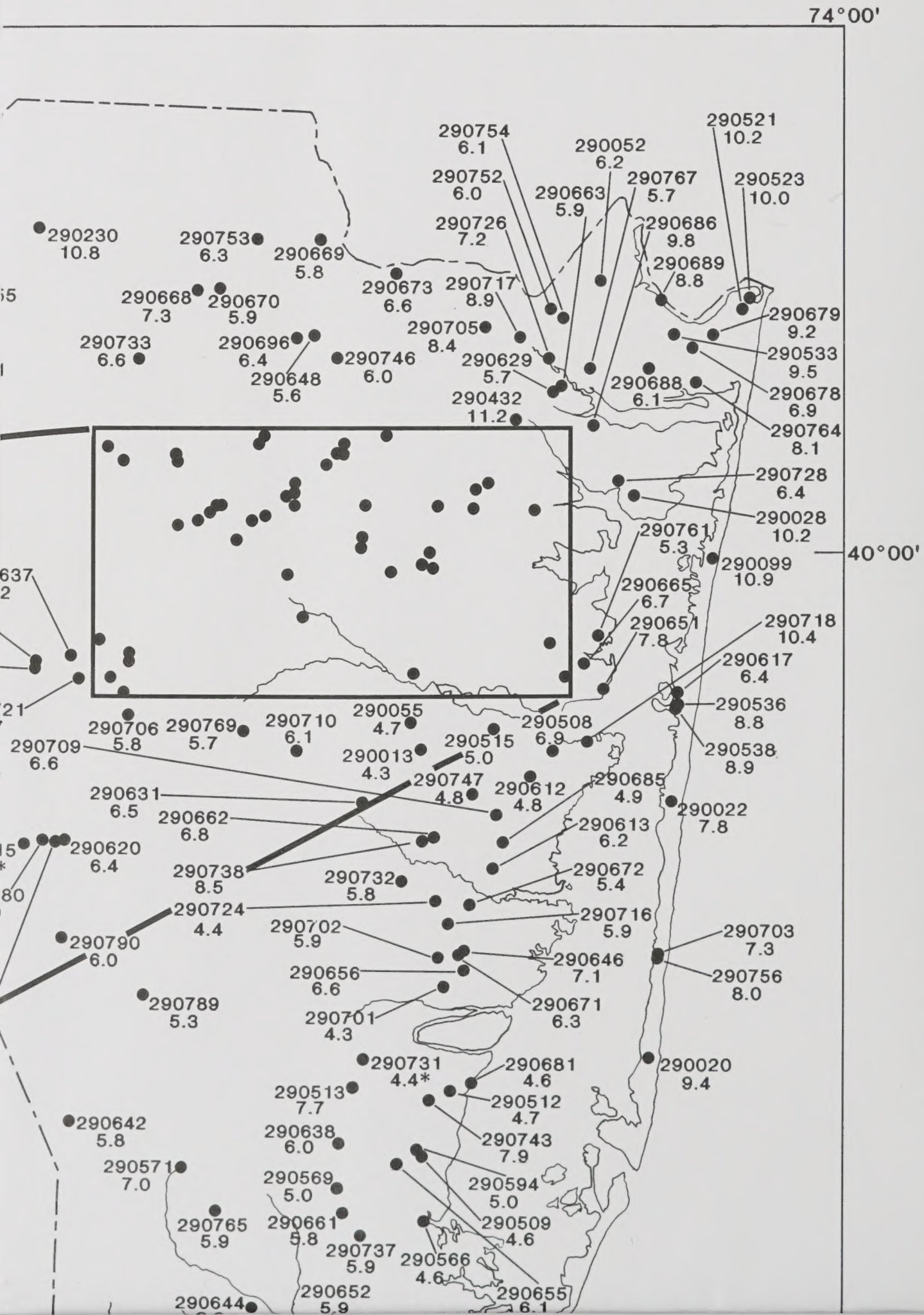
where SC is specific conductance.

DO solubility is converted to milligrams per liter by multiplying by 1.4276. This is corrected for barometric pressure by

$$DO' = DO^{o}\ (P-\mu)/(760-\mu),$$

where DO′ is saturation DO at barometric pressure P, and $DO^{o}$ is saturation DO at 760 mm mercury, and $\mu$ is the vapor pressure of water. The calculation for $\mu$ is:

$$\log \mu = 8.10765 - (1750.286/235 + T\ ^{o}C).$$


74°00'
40°00'
290230 10.8
290753 6.3
290669 5.8
290668 7.3
290670 5.9
290673 6.6
290733 6.6
290696 6.4
290648 5.6
290746 6.0
290754 6.1
290752 6.0
290726 7.2
290717 8.9
290705 8.4
290629 5.7
290432 11.2
290663 5.9
290052 6.2
290767 5.7
290686 9.8
290689 8.8
290521 10.2
290523 10.0
290679 9.2
290533 9.5
290678 6.9
290764 8.1
290688 6.1
290728 6.4
290028 10.2
290761 5.3
290099 10.9
290665 6.7
290651 7.8
290718 10.4
290617 6.4
290536 8.8
290538 8.9
290685 4.9
290022 7.8
290613 6.2
290672 5.4
290716 5.9
290703 7.3
290756 8.0
290646 7.1
290671 6.3
290701 4.3
290731 4.4*
290681 4.6
290512 4.7
290743 7.9
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290566 4.6
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290020 9.4
290737 5.9
290652 5.9
290644
290765 5.9
290661 5.8
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290569 5.0
290571 7.0
290642 5.8
290789 5.3
290790 6.0
290724 4.4
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290631 6.5
290662 6.8
290620 6.4
290709 6.6
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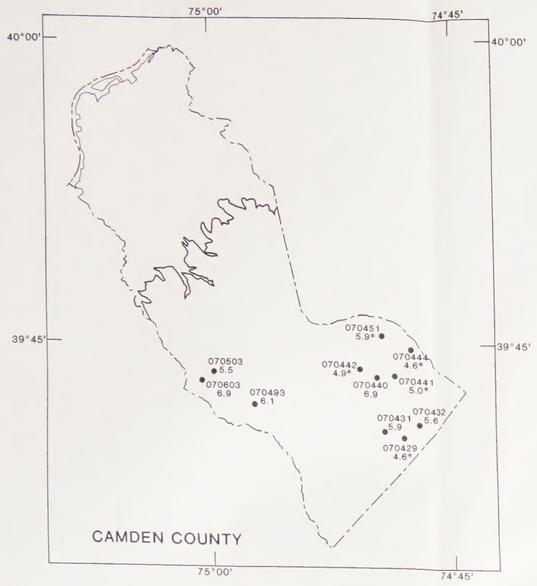
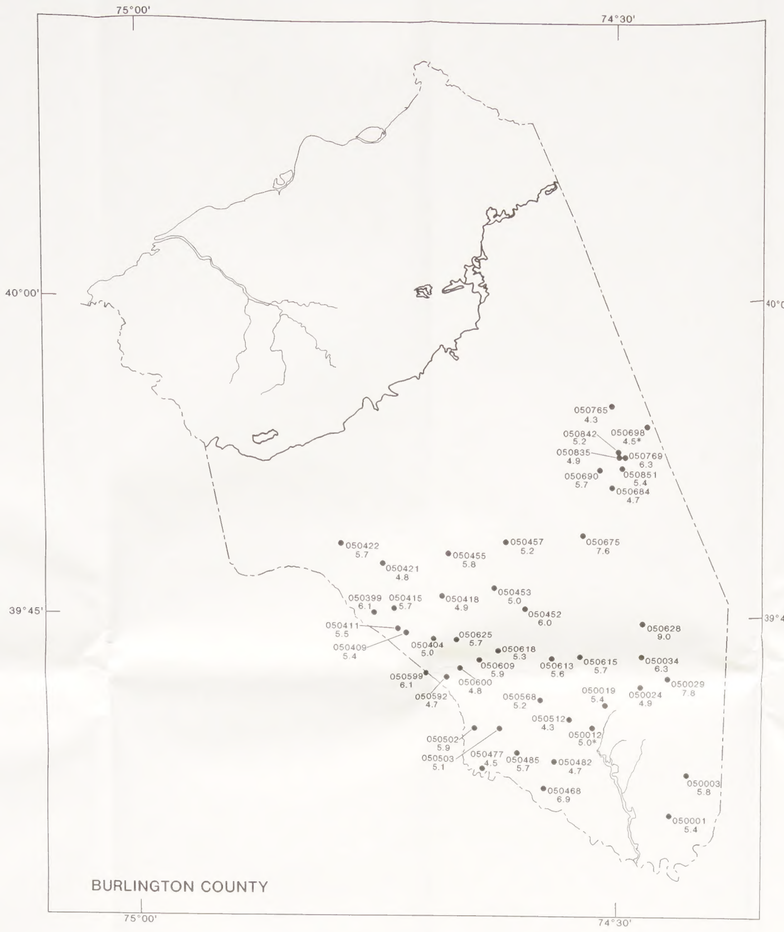
290769 5.7
290710 6.1
290055 4.7
290013 4.3
290515 5.0
290747 4.8
290612 4.8
290508 6.9

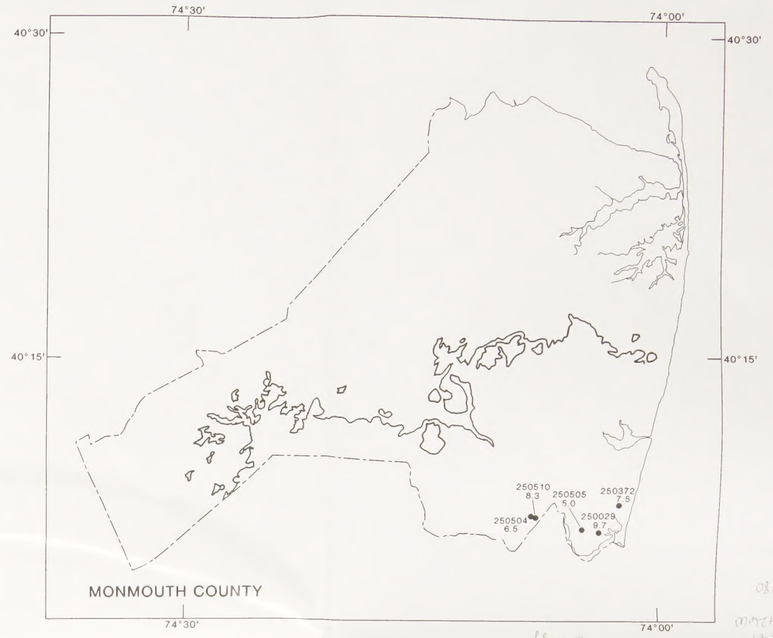
U.S DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

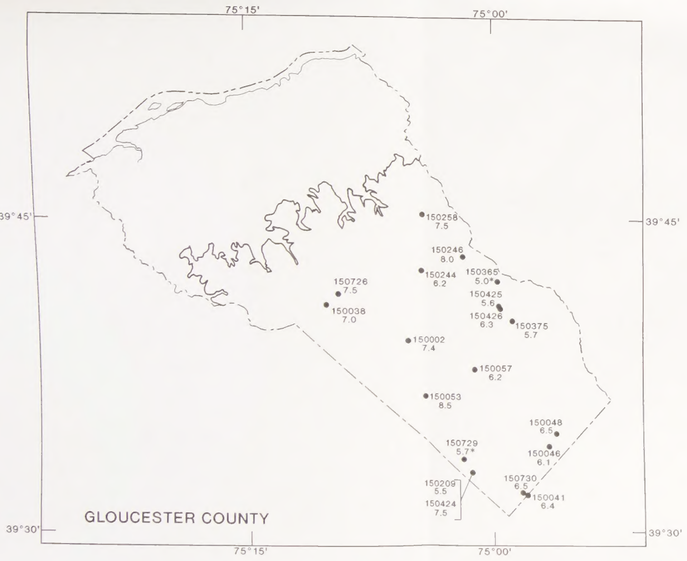
Prepared in cooperation with the
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ENERGY

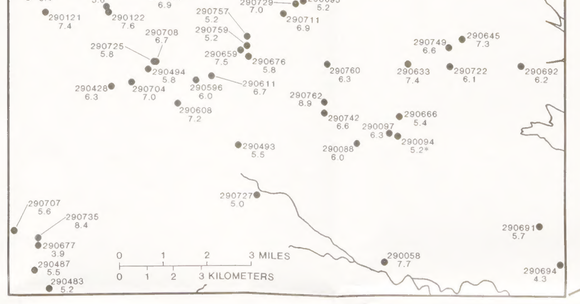
WATER-RESOURCES INVESTIGATIONS REPORT 90-4180
PLATE 1

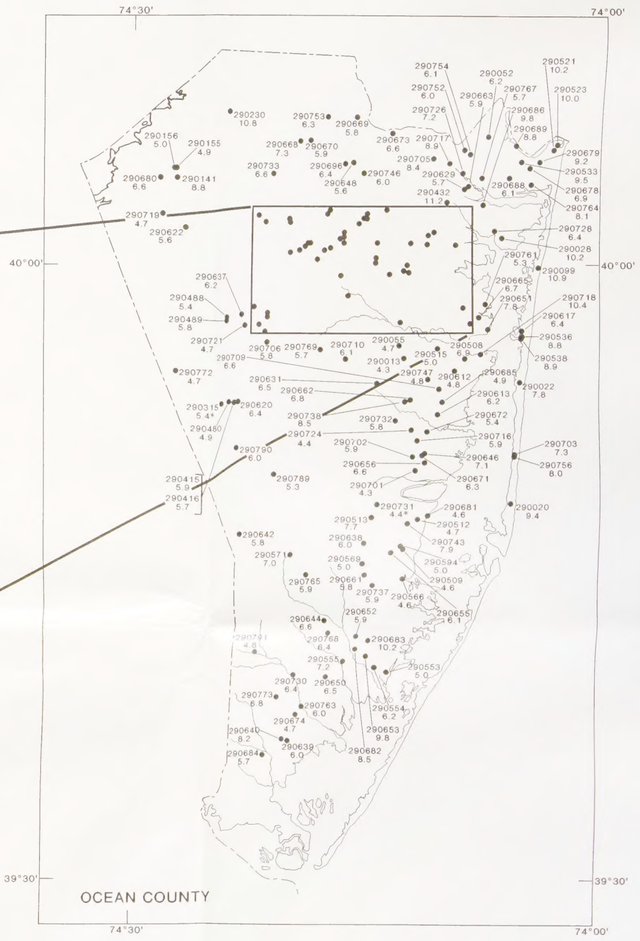


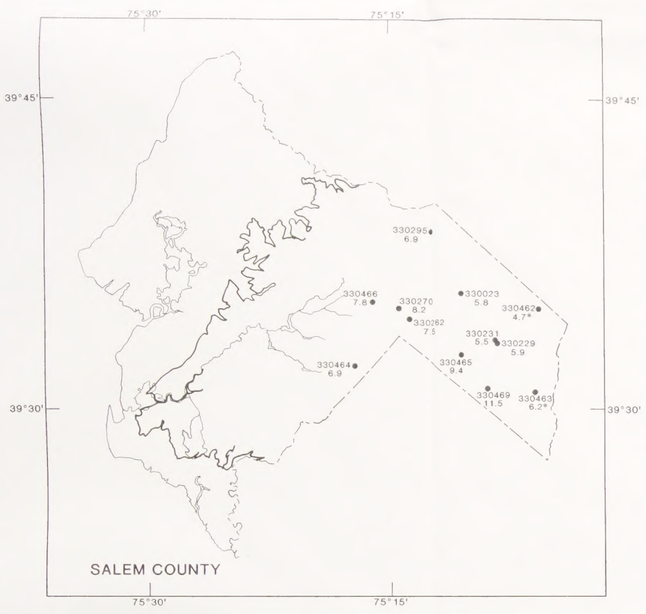



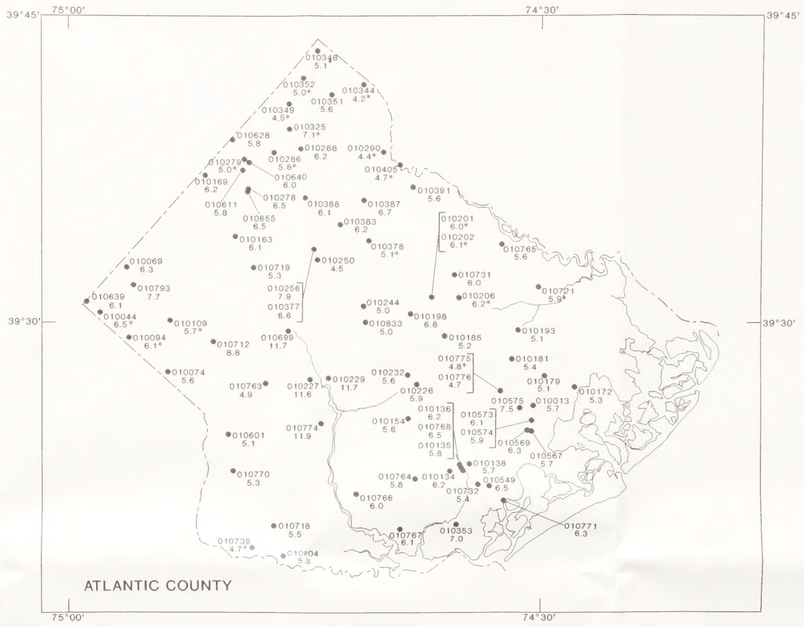







EXPLANATION

COUNTY BOUNDARY

UPDIP EXTENT OF THE KIRKWOOD FORMATION

010739 4.7* WELL SITE--Upper number is U.S. Geological Survey well number. Lower number is the Aggressive Index. An asterisk (*) denotes alkalinity of less than 1 milligram per liter

AGGRESSIVE INDEX

| | |
|---|---|
| AI is less than 10.0 | Highly aggressive (corrosive) |
| AI is 10.0 to 11.9 | Moderately aggressive |
| AI is greater than or equal to 12.0 | Non-aggressive (noncorrosive) |

SCALE 1:250 000

5 0 5 MILES
5 0 5 KILOMETERS

# AGGRESSIVE INDEX OF GROUND WATER IN THE KIRKWOOD-COHANSEY AQUIFER SYSTEM OF THE NEW JERSEY COASTAL PLAIN

UNIVERSITY OF ILLINOIS-URBANA

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